Vol. 34, No. 5 October, 1944

Journal of Experimental Psychology

EDITED BY
SAMUEL W. FERNBERGER, ON LEAVE
FRANCIS W. IRWIN, ACTING EDITOR
UNIVERSITY OF PENNSYLVANIA

CONSULTING EDITORS

CHARLES W. BRAY, *Princeton University;* ELMER K. CULLER, *University of Rochester;* CLARENCE H. GRAHAM, *Brown University;* JOY P. GUILFORD, *University of Southern California;* FRANCIS W. IRWIN, *University of Pennsylvania;* DONALD G. MARQUIS, *Yale University;* ARTHUR W. MELTON, *University of Missouri;* CARROLL C. PRATT, *Rutgers University.*

CONTENTS

Development of Behavior: The Micturition Pattern in the Dog: I. A. BERG .. 343

Hypnotic Recall of Material Learned Under Anxiety- and Non-Anxiety-Producing Conditions: B. G. ROSENTHAL 369

An Experimental Investigation of the Gradient of Reinforcement in Maze Learning: M. E. THOMPSON 390

The Retention of Verbal and of Motor Skills: H. J. LEAVITT AND H. SCHLOSBERG 404

A New Stabilometer for Measuring Dynamic Equilibrium in the Standing Position: R. C. TRAVIS 418

PUBLISHED BI-MONTHLY,
BY THE AMERICAN PSYCHOLOGICAL ASSOCIATION, INC.
PRINCE AND LEMON STS., LANCASTER, PA.
AND NORTHWESTERN UNIVERSITY, EVANSTON, ILLINOIS

Entered as second-class matter, February 6, 1937, at the post office at Lancaster, Pa., under the Act of March 3, 1879

PUBLICATIONS OF

THE AMERICAN PSYCHOLOGICAL ASSOCIATION

WILLARD L. VALENTINE, *Business Manager*

PSYCHOLOGICAL REVIEW

HERBERT S. LANGFELD, *Editor*
Princeton University

Contains original contributions only, appears bi-monthly, January, March, May, July, September, and November, the six numbers comprising a volume of about 540 pages.
Subscription: $5.50 (Foreign, $5.75). Single copies, $1.00.

PSYCHOLOGICAL BULLETIN

JOHN E. ANDERSON, *Editor*
University of Minnesota

Contains critical reviews of books and articles, psychological news and notes, university notices, and announcements. Appears monthly (10 issues), the annual volume comprising about 665 pages. Special issues of the BULLETIN consist of general reviews of recent work in some department of psychology.
Subscription: $7.00 (Foreign, $7.25). Single copies, 75c.

JOURNAL OF EXPERIMENTAL PSYCHOLOGY

S. W. FERNBERGER, *Editor, on Leave,* FRANCIS W. IRWIN, *Acting Editor*
University of Pennsylvania

Contains original contributions of an experimental character. Appears bi-monthly (beginning 1944), one volume per year, each volume of six numbers containing about 520 pages.
Subscription: $7.00 (Foreign, $7.25). Single copies, $1.25.

PSYCHOLOGICAL ABSTRACTS

WALTER S. HUNTER, *Editor*
Brown University

Appears monthly, the twelve numbers and an index supplement making a volume of about 700 pages. The journal is devoted to the publication of non-critical abstracts of the world's literature in psychology and closely related subjects.
Subscription: $7.00 (Foreign, $7.25). Single copies, 75c.

PSYCHOLOGICAL MONOGRAPHS

JOHN F. DASHIELL, *Editor*
University of North Carolina

Consist of longer researches or treatises or collections of laboratory studies which it is important to publish promptly and as units. The price of single numbers varies according to their size. The MONOGRAPHS appear at irregular intervals and are gathered into volumes of about 500 pages.
Subscription: $6.00 per volume (Foreign, $6.30).

JOURNAL OF ABNORMAL AND SOCIAL PSYCHOLOGY

GORDON W. ALLPORT, *Editor*
Harvard University

Appears quarterly, January, April, July, October, the four numbers comprising a volume of 560 pages. The journal contains original contributions in the field of abnormal and social psychology, reviews, notes and news.
Subscription: $5.00 (Foreign, $5.25). Single copies, $1.50.

JOURNAL OF APPLIED PSYCHOLOGY

DONALD G. PATERSON, *Editor*
University of Minnesota

Covers the applications of psychology in business, industry, education, etc. Appears bi-monthly, February, April, June, August, October, and December.
Subscription: $6.00. Single copies, $1.25.

Subscriptions, orders, and business communications should be sent to

THE AMERICAN PSYCHOLOGICAL ASSOCIATION, INC.

NORTHWESTERN UNIVERSITY, EVANSTON, ILLINOIS

XUM

Journal of
Experimental Psychology

VOL. 34, NO. 5 OCTOBER, 1944

DEVELOPMENT OF BEHAVIOR: THE MICTURITION PATTERN IN THE DOG

BY IRWIN AUGUST BERG[1]

University of Illinois

INTRODUCTION

Among psychologists, interest in behavior related to maturation has been continuing and widespread. This interest has sometimes provoked energetic controversies, as in the case of 'instinct' studies of earlier decades. Some areas of study, while offering numerous theories or hypotheses, have proceeded with serene but unflagging interest. Dextrality studies are an illustration of investigations in this latter area. But in all instances the opinion of those who study behavior related to maturation appears to be that their work is basic.

Many experimental investigations have concerned learning and its relationship to maturation. The work of Dennis (**15**) and Hilgard (**17**) with children are representative examples. In the case of animal work, Shepard and Breed (**29**) with their control over practice in the pecking of chicks gave impetus to a lengthy series of similar studies by many investigators.

Relatively few are studies dealing with behavior dependent upon maturation alone. The work of Coghill (**13**) in demonstrating how the extent of nervous development in Amblystoma is related to stages in swimming is a frequently quoted example. Another classic illustration is Carmichael's study (**12**) of swimming in tadpoles.

A field of current interest and expanding study concerns the role of hormones in relation to maturation and behavior. While most research in this area has been directed at copulatory behavior, a

[1] Condensed from a dissertation submitted in partial fulfillment of the requirements for the degree of doctor of philosophy in the University of Michigan (1942). The author wishes to acknowledge the friendly guidance of Professors J. F. Shepard, W. B. Pillsbury, W. C. Olson, B. D. Thuma, and L. R. Dice, all members of the doctoral committee. The Director and staff of the University of Michigan Laboratory of Vertebrate Biology are also to be thanked for providing the laboratory space required for this study.

XUM

number of more recent investigations have examined other behavioral items. Historically, Brown-Sequard (**10**) is probably responsible for the general interest in hormone activity. He injected testicular extracts in himself and experienced a marked increase in vigor and alertness which he concluded was due to the extract. Steinach (**30**) showed that the copulatory clasp reflex in male bullfrogs was abolished by castration and subsequently restored by the injection of testicular extracts. Stone (**33**) found that copulatory activity in the male rat waned after castration and that this activity was restored after injection of testosterone propionate, a male sex hormone. Ball and Stone (**1**, p. 1221) induced masculine behavior in female rats by means of testosterone propionate. Ball (**4**) found that the sex activity of four out of six male rats castrated when 4 months old was raised beyond the castrate level by injections of female sex hormones. Ball (**5**) also found male sex hormones administered to normal female rats resulted in a considerable increase in masculine sex behavior during the period of hormone injections and a rapid decrease in masculine behavior after the injections were stopped. Engel (**16**) found that the copulation pattern of castrated male rats was restored by the injection of hormones obtained from horse urine. Noble and Zitrin (**24**) administered testosterone propionate to young male chicks and estradiol benzoate, a female sex hormone, to female chicks. The treated male chicks crowed when about four days old and, when 15 days old, gave a complete, adult copulatory 'treading' response (the usual age for the appearance of this pattern is $4\frac{1}{2}$ months). The females to which estrogens were administered gave the female 'squatting' response to copulating males when about 20 days old. Using a hurdle box and observation cage, Seward (**26**) found castrated male guinea pigs revealed a gradual decline in crossings to reach a female, but that the number of crossings rose after testosterone injections.

In addition to the studies which have primarily been concerned with copulatory activity, there have been several investigations of hormonal action and maternal behavior. Kunde, D'Amour, Carlson, and Gustafson (**20**) produced lactation and maternal behavior in rats by estrin injections. Seward and Seward (**28**) obtained data which suggested that hormone activity was of prime significance in maternal behavior of guinea pigs. Hoskins (**18**, p. 184 f.) cites examples of the activity of the anterior pituitary lobe product *prolactin* in producing brooding of fowl, nesting of fish, and the adopting of mice, rabbits, and even squabs by young female rats.

Other studies have examined less specific behavior items or employed less direct control over hormones in relation to behavior. Anderson (**2**) found histological differences in certain endocrine glands

of various breeds of dogs and suggested (p. 648) that behavior peculiar to breeds of dogs ". . . might be dependent upon differences in glandular activity and quality." Beach (**8**) found a complete masculine copulatory pattern in some untreated female rats. He suggested (p. 140) that excessive androgenic activity of the ovaries or adrenals might be a causative factor.

A behavior item which has much to commend it from the standpoint of experimental investigation is micturition behavior of the dog. Micturition activity in dogs offers a sharp behavioral distinction between the sexes. All normal adult males elevate the leg when urinating, while normal females do not. Also, the response of the male is clear-cut and thus can be readily studied by methods such as photography, isolation, delay, etc. A further advantage is that studies of this behavior item might provide data useful for theoretical considerations of sex differentiated behavior. The urination pattern in the male suggests trial and error learning; yet maturation appears to be involved in that normal puppies never elevate the rear leg when urinating. Also, because of the sex difference in this behavior, hormone activity is a possible factor.

Procedure

Twenty-two animals, 16 males and six females, were employed in the study. Ten animals from three litters were secured from farms when between one and three months old. Eleven animals from two litters were born under laboratory control, and thus had contact only with members of their own litters and the dam. The remaining animal was about 10 years old when secured from a metropolitan dog pound. A number of other animals were used for observation but were not placed under experimental conditions. All experimental animals appeared to be in good health when secured. The largest dogs were about the size of Airdales; the smallest were about the size and appearance of Dachshunde.

The dogs were housed in an isolated, wooden, double-walled structure which had two fenced-in exercise yards. The temperature in the building varied from 41° to 83° F. during the year of the study. The animals were kept in cages, usually several littermates to a cage. The cages were so constructed that the animals could not see other animals in nearby cages except when they were being carried to the exercise yard. Dogs undergoing hormone treatment were placed alone in a cage.

The animals were initially placed on a diet of canned and dry dog food and, up to the age of 14 weeks, condensed milk was included. Twice a week each animal was given 5 cc. of codliver oil. This diet was later found to be inadequate and raw beef, condensed milk, and codliver oil were substituted. This temporary diet inadequacy will be considered later. Water was supplied daily for a four hour period only. It was found that withholding water overnight and then permitting the animals all the water they desired during the observation period usually resulted in their urinating when placed in the exercise yard.

The animals were usually placed in the exercise yard with their littermates when observed, although observation of a single animal occasionally was employed. Each dog was observed on alternate days. Once each week a photographic record with a 16 mm. motion-picture camera was made of urination activity. Frames from these records were enlarged and used for the accompanying figures. Because camera 'angles' were not equally revealing for all dogs, there has necessarily been selection in the choice of figures.[2]

[2] Additional photographs are included in the thesis filed under the title of this article at the University of Michigan. Also, the experimental procedure is given in greater detail.

Practice in the delayed animals, 3b and 4d, was controlled by placing the dogs on a treadmill inside a narrow cage. Slings were placed under the chest, abdomen, and hind legs (Fig. 1). This arrangement permitted the animal to move his legs in a forward direction on the treadmill; how-

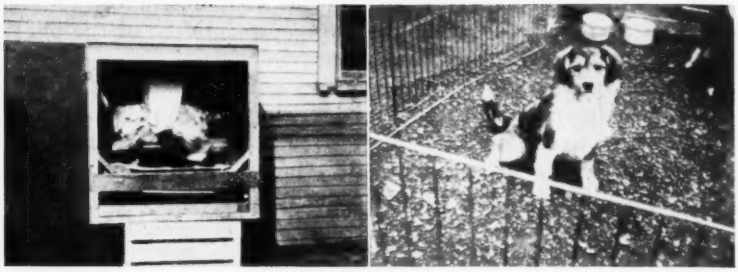

FIG. 1. Animal 3b. Slings under the hind legs were added later
FIG. 2. Animal 1b, 6 months old

ever the closeness of the side walls and the sling prevented the animal from elevating his leg. Each of the two delayed dogs was placed in the apparatus before his male littermates had elevated the leg when urinating, and was kept there until several weeks after the male littermate controls were regularly elevating the leg when urinating.

TABLE I

THE EXPERIMENTAL PLAN

Litter	Animal	Treatment
1. Secured when 12 weeks old	a. male	control
	b. female	conditioning
2. Secured when 4 weeks old	a. male	control *
	b. male	castrated
	c. female	control
3. Secured when 5 weeks old	a. male	castrated
	b. male	delayed *
	c. male	control *
	d. male	control
	e. female	male sex hormone
4. Born under laboratory control	a. male	castrated
	b. male	anosmic
	c. male	control
	d. male	delayed
	e. female	control
	f. female	male sex hormone
5. Born under laboratory control	a. male	male sex hormone
	b. male	anosmic
	c. male	anosmic
	d. male	control
	e. male	control
6. Secured when about 10 years old	a. female	male sex hormone

* After these animals had served as controls, they were used to study the effect of female sex hormone injections.

Castration of three animals was accomplished by complete removal of both testicles.[3] Of the dogs rendered anosmic, the nerve endings of the nasal fissure were coagulated in one animal, and the olfactory bulbs were removed in two other animals.

Because very old or ovarectomized female dogs are sometimes known to elevate the leg when urinating, it was planned to use male sex hormones in an attempt to produce similar leg-elevation behavior in females. Also, it was planned to attempt to produce female leg-raising by means of conditioning. Injections of male sex hormones were given to castrated animals and to very young puppies, and the effects of such treatment observed. Female sex hormones[4] were administered to normal adult male dogs in an attempt to disrupt the adult leg elevation behavior.

Results

The urination pattern in puppies.—In very young male and female puppies, i.e., those less than two weeks old, there is no urination posture. They urinate while creeping, while lying on the side, or while nursing. About once every hour or hour and one half, a small quantity of urine is released. The release of urine is in the form of a trickle, suggesting that when a certain fullness of the bladder occurred the sphincter relaxed. At this stage, the bladder-emptying appears to be mechanically controlled rather than under nervous control.

TABLE II

Average Number of Acts of Urination per Two-Hour Observation Period *

Age in Weeks	Females (Normal)	Males (Normal)
0–4	1.1	1.2
5–8	1.0	1.4
9–12	0.6	0.9
15–16	0.8	3.4
17–20	1.3	8.3
21–24	1.1	11.7
25–28	1.1	9.8
29–32	1.0	12.4

* The total number of observation periods was 103. The total number of acts of urination observed was 2317. Four to six females and 10 to 16 males were observed in securing the data. The number of animals varied for observation periods because of experimental conditions. Records were not included for experimental animals.

Between the ages of three to five weeks, a differentiation in the urination posture appeared between the male and female puppies of the group studied. All female dogs squatted on the hind legs in a characteristic posture when urinating (Fig. 2). This posture is quite similar to the defecation posture of both males and females. The male puppies, on the other hand, stood when urinating. The

[3] The author wishes to express his thanks to Dr. Vincent Rees and to Mr. William Troy of the University of Michigan Department of Surgery for performing the operations required in this study.

[4] The author is indebted to Dr. Oliver Kamm of Parke, Davis and Company and to Dr. Erwin Schwenk of Schering Corporation for supplies of sex hormones manufactured by their respective firms. Without their friendly cooperation this investigation would have been greatly handicapped.

hindquarters of the younger puppies were observed to be held relatively lower, in a semi-squatting position. As male puppies matured they stood relatively more erect (Fig. 3). This last was only a tendency; that is, some male puppies of the groups observed rarely squatted very low when urinating. At no time did a normal

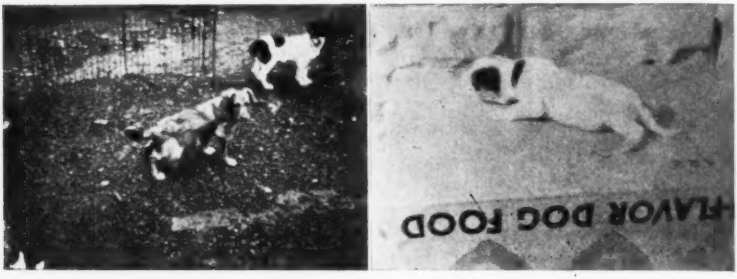

FIG. 3. Animal 3b, 7 weeks old
FIG. 4. Animal 5c. Locomotion when 7 days old

puppy in any of the groups studied elevate the leg when urinating before the age of 19 weeks.

With increasing age, the male puppies urinated less copiously but more frequently than the females. During a two-hour observation period, each female usually urinated once, although occasionally a female urinated twice or not at all. The female puppies urinated copiously, apparently emptying the bladder in one act of urination. Up to the age of 12 weeks the same was true of the male puppies. After the age of 12 weeks the males urinated more frequently and 'sniffed' the ground more often, although they did not elevate the leg when urinating until some weeks later.

Locomotion in the very young puppy is accomplished mainly with

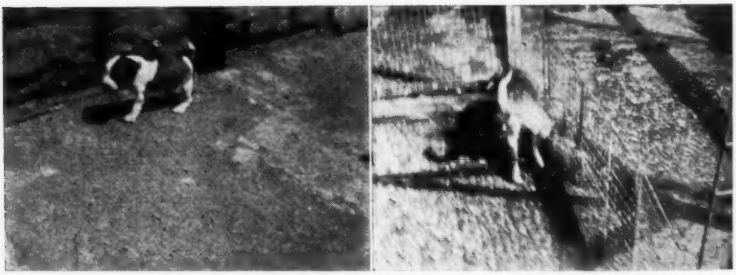

FIG. 5. Animal 5e, 27 days old
FIG. 6. Animal 5e. Initial stage of leg-elevation at 23 weeks

TABLE III

AGE OF FIRST APPEARANCE OF LEG-ELEVATION

Animal	1a	2a	3b*	3c	3d	4c	5d	5e	Mean
Age in Weeks	43	36	24	19	20	35	24	23	28.0

* This animal was delayed in a sling; hence the true age of the appearance of leg-elevation behavior may have been about 20 or 21 weeks.

the forepaws, the hindquarters dragging or moving in a manner uncoördinated with forequarter action (Fig. 4). The direction of locomotor development appears to be clearly caphalo-caudal. When two or three weeks old the animals walked erect, but not in the digitograde mode of progression characteristic of the adult dog. Instead, the entire plantar surface of the hind leg was in contact with the ground, much like the hind leg of a rabbit (Fig. 5). In the group of animals studied, no urination posture was noted in males or females until after the animals walked erect in a fairly well-coördinated manner. Also, no male elevated the leg when urinating until

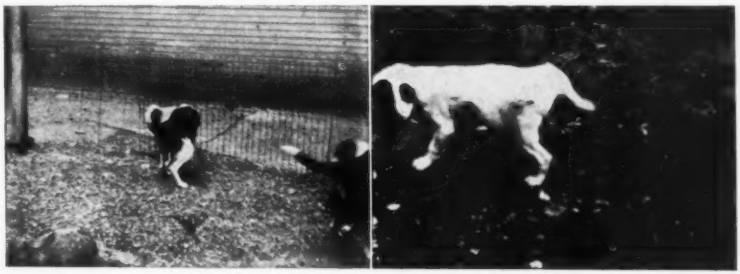

FIG. 7. Animal 2a. Torsion movement of back during urination—age 36 weeks
FIG. 8. Animal 5a. Leg not crooked—age 9 weeks

some weeks after the assumption of a digitograde position during walking. It should be noted that two-week-old pups were observed to *rise* to a digitograde position, but they were not observed to walk or run in this position.

The adult male urination pattern.—Several stages in the development of leg-elevation behavior were found. Initially, there was a gross torsion movement of the hindquarters in which large muscle groups were brought into action and the leg was lifted one or two in. from the ground (Fig. 6). Occasionally, the leg remained touching the ground although the torsion movement was clearly present (Fig. 7). The next stage was a higher leg-elevation in which the leg was moved outward from a point of articulation at the hip without

the leg's being crooked or drawn in close to the body (Figs. 8, 14). The third stage consisted in the bending or crooking the center of the leg and drawing it close to the body (Fig. 9). The only changes with increasing age noted in the behavior sequence after this third stage were a higher elevation of the leg (Fig. 10) and, in two animals, a more complete individuation of the leg-elevation pattern so that the toes of the paw were splayed.

Thus, the leg-elevation pattern was found to consist of stages in which activity progressed from the hindquarters to the hip, from the hip to the center of the leg, and in two cases to the toes of the paw. The emergence of this pattern was strongly suggestive of a proximo-distal direction of development.

The leg-elevation pattern required two to three weeks to develop from the initial torsion movement of the hindquarters during urina-

FIG. 9. Animal 3b. Urination in open—age 26 weeks
FIG. 10. Animal 3c. Adult urination posture—age 27 weeks

tion to the complete act of leg-flexion articulated at the hip. During this early period of leg-elevation, the animals frequently urinated in the open—that is, urinated without directing the stream against an object as a wall or a post. Also, some animals would approach a wall and then urinate away from the wall (Fig. 9).

Regression to puppy urination posture.—Adult male dogs that had been regularly elevating the leg when urinating were observed to revert to the puppy posture after being exposed to what may be called fear-arousing situations. This was first noticed in an adult male that had been observed to elevate the leg 231 times without assuming the puppy posture. This dog was placed in the exercise yard for observation when a tree which workmen had been felling nearby crashed to the earth. The dog yelped and cringed. The animal then crawled to the experimenter, its hind feet in a plantigrade position. Shortly afterward, the animal urinated, assuming the

puppy stance. The following day the leg was elevated in the normal adult manner.

Five males that had elevated the leg when urinating 100 or more times were subjected to stimuli such as a smart slap on the nose, an electric shock from a Ford spark coil, and a loud noise obtained by bursting inflated paper bags near the animal's head. In a total of 29 trials with such stimuli the dogs regressed to the puppy posture in 28 cases. The single exception occurred when a paper bag was burst and the noise did not appear to be as loud as was found in later trials with other paper bags.

Control of practice in leg-elevation.—Practice was controlled by placing the animal in a treadmill cage (Fig. 1) designed to control leg-elevation. Animals 3b and 4d were placed in the apparatus during different periods; however, animal 4d contracted distemper and died before his delay period was complete. Thus, only the results of dog 3b are available.

Animal 3b was strapped in the delay apparatus when 15 weeks old. Neither this animal nor any of his normal littermates elevated the leg at this age. The animal was not removed from the delay cage until the end of the delay period; feeding and cage cleaning were done while the animal was in the delay harness. The dog appeared to adjust well to the delay condition in about a week's time. When 19 weeks old, this animal's littermate, 3c, showed the leg-elevation pattern when urinating. A week later, littermate 3d also revealed the pattern. Although the delay animal was observed daily when urinating, he made no attempt to elevate the leg when urinating. The slings and narrow cage would, of course, have prevented complete leg-raising; however, it is stressed that the animal was not observed to make even a partial leg-flexion. The dog was kept continuously in the delay apparatus for a total of nine weeks until almost 24 weeks old. At this age his control littermates 3c and 3d had been raising the leg when urinating for five and four weeks respectively.

At the end of the delay period, the animal was fed and given milk before being removed from the cage and placed in the exercise yard. When placed outdoors, the animal cowered on the ground and crept after the experimenter. The animal did not urinate or make any attempt to explore the exercise pen. The dog was then returned to the cage, and shortly afterward he urinated copiously. On the second day, food and milk were placed in the yard, but the animal refused to eat and did not urinate outdoors. On the third day, a female littermate was placed outside with the delay animal and a large quantity of meat and milk were placed in the yard. The female ate readily; the delay animal ate more hesitantly. In five hours each animal urinated once. The male assumed a puppy

urination stance. After being removed from the delay cage on the fourth day, the animal did not cringe when placed outside. He ate readily and drank a large amount of milk. About a half-hour afterward he urinated, raising the leg completely. It was a complete, individuated leg-elevation. The animal did not direct the urine stream against an object but urinated in the open (Fig. 9). He continued to elevate the leg regularly, although for several weeks he did not urinate on objects such as a post or wall.

Another control over practice was instituted in a less complete manner. Animal 5e was placed alone in a cage when six weeks old. He was not allowed to exercise in the yard. Also, his cage was so placed that he could not see other animals. Thus, there was no opportunity to learn by imitation, nor was the olfactory stimulus of urine from other animals immediately available except for such odors as might come from a distance of 20 feet. Trial and error learning, of course, was possible. Under these conditions the animal elevated his leg when 23 weeks old, the first of his litter to do so.

Results of castration.—Three males of different litters, animals 2b, 3a, and 4a, were castrated by complete removal of both testicles when 11, 7, and 4 weeks old respectively. Animal 4a died five days after the operation, apparently as a result of post-operative infection. The remaining dogs were observed on alternate days. Both animals continued to assume the puppy urination stance for several months after their control littermates had been regularly raising the leg when urinating.

When 41 weeks old, dog 2b had not been observed to make any attempt to raise his leg during urination, although his control littermate had been elevating the leg for five weeks. At this time 25 mg. of testosterone propionate in one cc. of sesame oil was injected intramuscularly in the buttock on alternate days for four days, a total of 100 mg. testosterone propionate. On the ninth day after the initial injection the animal raised his leg completely when urinating. No further injections were given, and on the sixteenth day the dog reverted to the puppy urination posture. No further changes in posture were noted thereafter. On the twenty-fifth day after the first injection the animal became ill with what was apparently distemper. Although treated with sulfapyridine as suggested by Troy (**37**) the animal died two weeks later.

Castrated animal 3a continued to reveal the puppy urination stance up to the age of 33 weeks, although his control littermates had been elevating the leg during urination for 10 or more weeks. This castrated animal was given 25 mg. of testosterone propionate in one cc. sesame oil injected in the buttocks on alternate days. After the third injection it was observed that the frequency of urination

increased from two to three times in a 1½ hour observation period to seven to nine times, although the leg was not elevated. After six injections of testosterone, 13 days after the initial injection, the animal elevated his leg completely when urinating. The leg-elevation was completely individuated, including a crooking of the leg (Fig. 11).

The animal continued elevating the leg for six days after the last injection of testosterone. On the seventh day and for four days

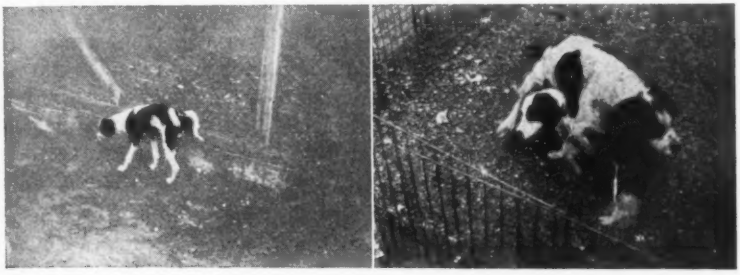

FIG. 11. Animal 3a (castrate). Urination posture after testosterone treatment—age, 32 weeks
FIG. 12. Female 6a mounting female 4c after testosterone treatment

afterward the animal reverted to the puppy posture when urinating. Frequency of acts of urination also decreased. Then, one 25 mg. injection of testosterone was administered on the eleventh day after the last injection. This was the seventh 25 mg. unit administered. On the day following, the animal urinated four times in a 1½ hour period, elevating the leg once and assuming the puppy posture three times. Thereafter, no reversion to the puppy posture occurred until the fourth day after the last hormone injection. Of two acts of urination on the fourth day, one was in the puppy posture. On succeeding days the puppy posture was employed exclusively. No testosterone was administered for 22 days after the seventh injection. Beginning with the 23rd day, injections 8, 9, and 10 of 25 mg. of testosterone each were administered on alternate days. The puppy urination stance was observed to persist until the day after injection 10. The animal continued to elevate the leg when urinating for five days after injection 10 without additional hormone treatment. After the fifth day, a reversion to the puppy stance was observed which continued until injection 11.

Injection 11 was also 25 mg. testosterone. This injection was administered nine days after injection 10. On the day following injection 11, the animal elevated the leg completely and continued to do so for five days. On the fifth day, the animal returned to the

puppy urination posture. The animal was observed daily for two weeks after the return to the puppy which followed injection 11 and on alternate days for six additional weeks, but no leg-elevation during urination was observed. During the last four weeks of this period, the animal was allowed to remain all day in the exercise yard with a normal adult male, in order to check for the possible influence of imitation. No postural change occurred in either animal. The castrated animal continued to assume the puppy stance during urination.

Estrogen administration to adult male dogs.—Since leg-elevation in castrated male dogs appeared to relate to the presence of a male sex hormone, it was planned to attempt to break the leg-elevation pattern in normal adult males by the injection of female sex hormones. After animal 3b had completed the delay period and after animals 3c and 2a (controls) had been elevating the leg during urination for several months, they were treated with theelin and estradiol benzoate, female sex hormones. Animals 3b and 2a were injected with theelin, animal 3c with estradiol benzoate. Because nothing in the literature suggested an optimal dose for studying the effects of estrogens upon the behavior of dogs, large doses were employed at first.

The first animal thus treated was 3c. This animal was given 10,000 I.U. estradiol benzoate each day for eight consecutive days. Half of the dose was injected in each buttock. The results of this treatment were striking. The leg-elevation pattern was not broken, but rather reinforced. The animal urinated with increasing frequency, elevating the leg each time. After the first six or seven leg-elevations no further urine was expelled; however the animal continued to sniff about walls and posts and briefly elevate the leg.

The animal's behavior might best be described as *frantic*. He literally spent all of his time in darting about the exercise yard, pausing briefly to elevate the leg for one or two seconds. Urine was expelled during the first six or seven acts of leg-elevation. These first leg-elevations were of longer duration. No urine was expelled afterward, although leg-elevation continued, sometimes as often as 70 times in a half hour (Table III). The animal appeared to be oblivious to stimuli which previously had had marked attention value. Formerly, the passing of a freight train nearby would cause the animal to prick up his ears and then bark. The animal also had played with a stick or an old rag quite frequently when in the exercise yard. None of this earlier behavior was observed during the period of 'frantic urination.' The animal appeared concerned only with darting about the yard, sniffing, and raising the leg. When allowed in the yard for several hours, the animal eventually fell asleep. Also, the animal appeared to sleep much more than the other dogs

TABLE III

LEG-ELEVATION OF ANIMAL 3c AFTER ESTROGEN TREATMENT

Day	Number of Leg-Elevations	Period of Observation (Min.)	Average No. Elevations Per Min.
*4	14	20	.70
*5	27	33	.82
*6	32	35	.91
*7	76	30	2.53
*8	72	31	2.32
9	139	64	2.17
10	61	28	2.18
11	11	67	.16
12	15	41	.36
16	3	22	.14
23	3	36	.08

* On these days and on the three days preceding, 10,000 I.U. estradiol benzoate were administered.

when confined in the cage. Animals 3b and 2a manifested the same pattern with similarly large injections of theelin.

These results were discussed with Professor A. E. Woodward of the University of Michigan Zoölogy Department. She suggested using smaller doses of estrogens. Accordingly, animal 3c was given 1000 I.U. estradiol benzoate on alternate days for 11 days. Animals 2a and 3b were given 2000 I.U. theelin on alternate days for 11 days. Each animal had a total of six injections. The hormones were administered four weeks after the end of the previous series of 10,000 I.U. daily.

Animal 3c reverted to the puppy posture on the day following the sixth injection, the twelfth day of the injection series. Animal 3b ceased elevating the leg during urination on the ninth day, the day of the fifth injection. Animal 2a became ill with distemper before the sixth injection of female sex hormones was administered. While this animal did employ the puppy urination posture, the disease may have influenced this pattern. It is known that distemper can result in chorea and similar nervous disorders (see Cannon, **11**, p. 16).

Administration of androgens to female dogs.—Dog owners sometimes report that old female dogs occasionally elevate the leg when urinating. Two females that manifested such behavior were observed by the experimenter, although they were not used in this experiment. One animal was a 15-year-old mongrel that had borne many litters; the other was a six-year-old spayed Boston terrier owned by Professor Willard C. Olson. Since one animal was past the litter-bearing state and since the other was ovarectomized, it was believed that a hormonal imbalance might relate to the leg-raising behavior. It was planned to attempt to secure similar leg-elevation behavior in females by the injection of testosterone propionate.

Two animals were used, animal 6a, about 10 years old, and animal 3e, 14 weeks old. Animal 6a had borne several litters, and animal 3e had never been in estrus.

Three periods of androgen administration were used with animal 6a. No hormones were given for 12 days between each period. During the first period, female 6a was given an injection of 25 mg. testosterone three times a week for three weeks, a total 10 injections, or 250 mg. testosterone. No change in urination posture was observed. There was a slight increase in frequency of urination during the last week of this period. In the second period an injection of 25 mg. testosterone was given daily for 10 days, a total of 250 mg. No change in posture was observed. The animal urinated an average of three times per two-hour observation period, which was about three times the normal frequency listed in Table II. During the third period, 37.5 mg. testosterone was injected daily for eight days, a total of 300 mg. The female urination posture remained unchanged. The frequency of urination was the same as the second period, or about three times the average for normal females. Thus, after a total of 800 mg. testosterone propionate was injected, no change in urination posture was found.

Animal 5e was given 16 injections of 25 mg. testosterone on alternate days, a total of 400 mg. No change in the urination posture was observed. The frequency of urination increased after the third injection from once to an average of two and one-half times during a two-hour period.

Although no changes in urination posture were observed in either animal, both females did reveal the male copulatory pattern. After the fifth 25 mg. injection, animal 6a mounted a young female. Animal 3e revealed similar behavior after the fifth injection. The mounting behavior was not always directed at the hindquarters of the mounted animal but frequently the head was mounted (Fig. 12). A male was let out in the exercise yard with animal 6a. Although the male struggled, he was firmly clasped and the female executed a series of rapid piston movements. With increasing doses of the male sex hormone, both animals more frequently mounted other males or females placed outside with them. Female 6a particularly was observed to mount other animals almost continuously during the two-hour observation period. Her mounting behavior was similar to the 'frantic' leg-elevation behavior of animals 3b and 3c. She would mount an animal, would be shaken off, and would immediately mount the animal again. Three weeks after the injections were discontinued she no longer revealed this copulatory behavior. Animal 3e ceased exhibiting the male copulatory pattern nine days after the last injection.

Androgens administered to an immature male dog.—Previous studies have demonstrated that testosterone administered to very young male rats or male chicks results in a premature appearance of the copulatory pattern. It was planned to treat a young puppy in a similar manner to observe the effect upon leg-elevation. When six weeks old, animal 5a was given 12½ mg. testosterone daily for 14 days. Because of the numerous observations being made of other animals, this animal was not observed until the day of the fourteenth injection when he was eight weeks old. On this day, the animal elevated the leg four times when urinating in a 35-minute period.[5] The leg-elevation was completely individuated, including crooking of the leg (Fig. 13). It is probable that the pattern appeared before

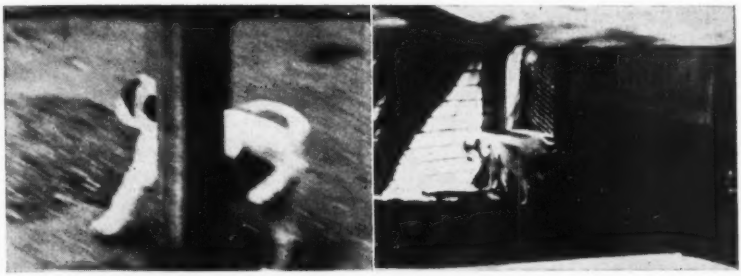

FIG. 13. Animal 5a. Leg-elevation at age 8 weeks. Treated with testosterone
FIG. 14. Animal 5a. Age 10 weeks. Treated with testosterone

this time but was not observed. The littermates of this animal did not elevate their legs when urinating until several months later, littermate 5d at 24 weeks and 5e at 23 weeks.

No testosterone was administered for two weeks after the close of the 14-day hormone injection period. It was observed that six days after the last hormone injection animal 5a revealed a less individuated urination posture in that the leg was not crooked (Fig. 8). Three days after this, nine days after the last injection, a reversion to the puppy posture occurred. When the animal was 10 weeks old, five mg. testosterone was injected in the buttocks daily for three days. On the day of the third injection, an incompletely individuated leg-elevation occurred during an act of urination. During a second act of urination, the puppy position was assumed. On the day following, a completely individuated leg-elevation was observed. This behavior continued without reversion to the puppy stance for 15 days. On the sixteenth and seventeenth days after the

[5] It is interesting to note that the testes of this animal had descended and were easily palpated at this time.

last injection a partially individuated leg-elevation was noted. Thereafter the puppy stance was employed without exception during urination for almost two months. When 20 weeks old, the animal began to elevate the leg regularly although no testosterone had been administered for more than nine weeks.

Attempted control of olfaction.—An attempt was made to render animal 4b anosmic by coagulating the nerve endings of the nasal fissure. The original plan called for excision of the olfactory bulbs; however, because of the thickness of the skull and danger to the eyes, this plan was abandoned. It was thought that the thinner and softer skull of puppies might make this operation less hazardous. When six days old, animal 5b was subjected to successful olfactory bulb excision, but the animal died about an hour later. Animal 5c was similarly operated on when 18 days old. This animal died three days later. The attempt to render animal 4b anosmic by coagulation of the nasal fissure nerve endings was likewise unsuccessful. Simple tests made with meat placed under inverted pans indicated that this animal could respond to olfactory stimuli.

Since surgical techniques were unsuccessful, an attempt to control olfaction was made by inserting a pellet of cotton dipped in oil of wormseed in the nostrils of animal 5d when he was 17 weeks old. The nostrils were carefully swabbed with petroleum jelly daily and a fresh cotton pellet was inserted. The animal adjusted to this condition and ate food readily after a week's time. This animal was observed on alternate days when 18 weeks old. He was placed in a small concrete floored pen several hours after the floor of the pen had been washed with a lysol and soap solution. Under these conditions the animal began to elevate the leg when urinating when 24 weeks old, a week later than his control littermate 5e. The only change noted in his behavior was that he did not sniff the ground as normal animals do. The animal did urinate on posts as if visual stimuli were related to this behavior.

Leg preference of adult male dogs during urination.—It was observed that animal 3d raised only the right leg when urinating. If he

TABLE IV

LEG PREFERENCE DURING URINATION

Male	No. Right-Leg-Elevations	No. Left-Leg-Elevations	Total
1a	51	69	120
2a	97	62	159
3b	88	51	139
3c	93	40	133
3d	247	0	247
Total	576	222	798

approached a wall or post from his left, he would raise the right leg and urinate away from the object. This was during the first few weeks of leg-elevation activity. Later, if he approached a wall from his left, he would turn around before raising the right leg so that the wall was now on the right. A record was kept for five weeks of the leg elevated by animals 1a, 2a, 3b, 3c, and 3d. These data are summarized in Table IV. It seems clear that some male dogs may exhibit a leg preference for acts of urination.

Discussion

Dog owners and kennel operators often refer to a male dog's 'learning to lift the leg' as if the process were of a trial and error nature. Yet, mere observation of a pattern of behavior gives no clue as to whether learning or maturation is responsible, as Maier and Schnierla (**22**, p. 374) remark. Two lines of evidence in this study oppose a trial and error interpretation of leg-elevation behavior in male dogs. First, there is the evidence of a cephalo-caudal direction of development which was followed by a proximo-distal direction of leg elevation behavior. The second line of evidence in this study concerns the results of castration, delay, and androgen administration to young puppies. That is, castrated animals should have 'learned' to lift the leg when urinating, but they did not. An animal delayed in a sling without opportunity to practice should have exhibited random, trial and error movements instead of a complete leg-elevation after being released from the delay cage. Also, male sex hormones administered to a young puppy should not have resulted in leg-elevation behavior at eight weeks and 'forgetting' of the pattern at nine weeks when hormone injections ceased.

Thus, maturation appears to be responsible for leg-elevation behavior in male dogs. This behavior is universal among normal adult males, and it is sufficiently complex to be designated as *instinctive*. What appears to be learned in canine micturition behavior is the directing of the urine streams against an object such as a wall or post. During the early stages of the appearance of the pattern, it was noted that several animals frequently urinated in the open or away from an object. Older males rarely did this.

The age at which leg-elevation first occurred during urination may have been affected by temporary dietary deficiencies in the case of litters 1 and 2. While dog owners report ages as high as 11 months for the appearance of leg-elevation behavior, it is possible that dietary deficiencies may cause a delay in the appearance of this pattern in such cases also. Allen (**1**, p. 1173) states that vitamin B deprivation is known to result in atrophy of the sex organs and

reduced testicular hormone output. Stone (**32**) found that qualitative inanition caused a delay in the appearance of copulatory activity in white rats. Since a testicular hormone was shown to relate to leg-elevation in males and since a vitamin B1 deficiency was found to exist temporarily in the diet of litters one and two, it is possible that a delay in the appearance of this pattern may have occurred in some cases.

Milk was omitted from the diet of all animals at age 15 weeks. The two oldest groups, the animals of litters 1 and 2 began to refuse food, becoming extremely timorous at the approach of the experimenter, shortly after the exclusion of milk from the diet. Some animals had several convulsive seizures, and animal 1a exhibited a paralysis of the hindquarters. The symptoms and course of this disorder were quite like those of 'fright disease' as described by Patton (**25**). Patton pointed out that thiamin chloride, vitamin B1, was heat labile and thus destroyed by autoclaving. He emphasized that animals fed exclusively on prepared dog's foods were receiving a diet deficient in B1 unless this vitamin were later added, because the high temperatures destroyed the vitamin. In accordance with his suggestions 600 I.U. thiamin chloride in sterile distilled water was injected subcutaneously.

The effect of the B1 injections was striking. Within six hours after the first injection all animals drank a small amount of beef broth which had previously been ignored. The paralysis of animal 1a disappeared within eight hours. Similar injections were given for three more days. By the fourth day the animals appeared to be quite normal. Thereafter, raw beef and milk were fed daily, since these foods contain adequate amounts of B1. The prepared dog foods were eliminated from the diet. No further evidence of avitaminosis was noted during the remainder of the experimental period.

The results of the castration experiments are considered to be sufficiently well delineated to permit a direct interpretation. It is known that androgens appear in quantity at the time of puberty in normal males (see Best and Taylor, **9**, p. 1196f.). Studies already cited have demonstrated that male copulatory behavior is normally absent in castrated adult rats; however, when such animals were treated with sex hormones the copulatory pattern was restored, The failure of castrated males in this study to reveal the adult male leg elevation behavior is considered to be similar to the absence of copulatory activity in castrated male animals reported in other studies.

The action of the male sex hormone used in the castration experiments appears to be an activating or energizing of an existing but hitherto inactive neural or neuromuscular organization. It cannot

be assumed that the action of the hormone is to produce nerve growth and thus form the necessary sensori-motor connections, since if this were the case there should be no reversion to the puppy stance after hormone injections were halted. It will be recalled that the leg-elevation pattern was made to appear and disappear four times in castrated animal 3a. Further evidence that arrested nerve development is not a likely explanation for these results is found in the work of Kudanoff (**19**), who observed that nerve endings in the genital area of mice castrated shortly after birth continued their development. Other evidence which will be presented later indicates that the neural organization concerned with this behavior is probably matured at birth or shortly afterward.

The results of androgen administration to females permit several interpretations. Since the attempts to produce this pattern by means of hormone injections were unsuccessful, it may be that some explanation other than hormonal may account for the leg-elevation of an occasional female, such as the animal belonging to Professor Olson. It is possible that while maturation is responsible for leg-elevation in the male, trial and error learning or conditioning might relate to similar behavior in an occasional female. But the two females that were observed to elevate the leg during urination did so only half the time or less. Trial and error learning would suggest more regularity in the appearance of such behavior. Also, it should be expected that more variation would be observed in the female urination posture, instead of either a squatting posture or a complete hind-leg-elevation. The same arguments may be advanced against conditioning. An attempt was made to condition female 1b by administering an electric shock whenever an attempt to squat and urinate was made. No change in posture occurred even after she was shocked 39 times. A final significant point is that the two leg-elevating females observed, and similar females described by dog owners, are either ovarectomized or relatively old, suggesting an altered hormone condition.

Allen (**1**, p. 588) refers to endocrine intergrades. Some animals of various species are as much male as female from an endocrine standpoint, regardless of the appearance of the external genitalia. Such animals may show copulatory activity ordinarily associated with either or both sexes. Conceivably, such endocrine intergrades might explain the male leg-elevation behavior of certain females.

A third possible explanation is suggested by the work of Ball and of Beach. Ball (**5**, p. 164) concluded that ". . . the male copulatory pattern in more or less rudimentary form is part of the equipment of the normal female rat. The threshold of this behavior pattern is very high normally but it can be lowered by testosterone administration.

. . ." Beach (**8**) found that some *untreated* female rats revealed a complete male copulatory pattern. Stone (**31**) noted that some untreated male rats occasionally exhibit portions of the female copulation pattern. Such findings, as Beach states (**8**, p. 141), ". . . suggest that some individuals may inherit or acquire the neural organization mediating the mating pattern of the opposite sex."

These studies, while referring to copulatory behavior, may relate to the failure to secure female leg-elevation during urination. That is, the threshold may not have been lowered sufficiently to activate the male leg-elevation pattern, or these particular animals may have lacked the appropriate neural organization necessary for this pattern. Other female animals that do reveal the leg-elevation pattern would on this basis be said to possess the appropriate neural organization. Similarly, it might be assumed from this viewpoint that the threshold might have been lowered sufficiently to cause leg-elevation if testosterone had been administered for a longer period of time. It is possible that more conclusive results might be obtained by using ovarectomized animals in a similar study.

The administration of female sex hormones to normal males produced complications worthy of elaboration. The leg-elevation during adult male urination was ultimately disrupted and a reversion to the puppy urination posture occurred after treatment with estrogens. This suggests, as do the castration results, that the leg-elevation pattern is hormonally controlled. Morrell and Hart (**23**) found that testicular function was eventually suppressed by administration of estrogens such as stilbestrol. This would suggest that the prolonged administration of female sex hormones to the dogs used in this study may have suppressed testicular activity, resulting in lesser testosterone secretion and a reversion to the puppy urination posture. The cessation of the female sex hormone injections would then permit a gradual restoration of testicular function to an approximately normal level and, hence, a resumption of normal adult male leg-elevation behavior.

But the 'frantic' leg-elevation behavior which occurred when large (10,000 I.U.) injections of female sex hormones were administered is frankly puzzling. It will be recalled that treated males sometimes elevated the leg as often as 100 or more times in an hour, although no urine was expelled after the first seven or eight leg elevations, and then fell asleep. Dr. Gardner Riley of the University of Michigan Hospital has noted that large doses of estrogens appear to promote the formation of calci in the bladders of rats. Hence, it was at first thought that the frantic leg-raising might be the result of bladder irritation due to calci. But this explanation is inadequate, since it was later found that the frequency of leg-elevation dropped

with the cessation of estrogen administration. Calci in the bladder should be expected to provide a more constant irritation.

The results of Ball (3) suggest what appears to be a more tenable explanation. She found that administration of female sex hormones to castrated male rats resulted in an increase in sex activity in four of six animals. She suggested that gonadal hormones activate a mating pattern which is already present. It is possible that the existing and functioning leg-elevation patterns in the adult males used in this study were more strongly or more frequently activated by the estrogen treatment. Thus, while large amounts of female sex hormones were adequate to energize the leg-elevation pattern, small amounts were not. The use of small amounts of the hormone might be interpreted as being inadequate to cross or lower a threshold of the type described by Ball (3). Then, if testicular function had been suppressed as previously suggested, a reversion to the puppy urination stance would occur.

The leg-elevation behavior noted in an eight-weeks-old puppy treated with testosterone is analogous to the precocity in copulation described in studies by Stone and Noble and Zitrin which have already been cited. This behavior appeared two months earlier in the treated animal than in the control littermates. Such behavior might be explained as being due to increased neural growth resulting from the hormone treatment. But this is not likely; for if the action of testosterone were merely to hasten nerve development, then once this development had occurred the necessary connections should have been made and there should be no reversion to the puppy urination posture. The experimental animal did, however, return to the puppy position when testosterone was no longer administered.

It might, of course, be assumed that testosterone speeded nerve development and then activated the matured sensori-motor organization. On this basis, the reversion to the puppy stance occurred because the hormone activator was no longer present although the neural organization was mature. Such an interpretation is possible. However, as already discussed, other studies indicate that the neural organization of the mating pattern is complete at birth or shortly afterward. It is believed likely that the sensori-motor basis for the leg-elevation pattern in male dogs is similarly present at birth or shortly thereafter, since no studies of similar behavior indicate that under similar conditions testosterone promotes nerve growth.

A hypothesis concerning individuation in canine leg elevation.—If it is assumed, as it is in this paper, that the nervous organization mediating leg-elevation behavior during urination of adult male dogs is complete shortly after birth, it is necessary to explain how individuation in such leg-elevation behavior can occur. The increasing

specificity of sensori-motor connections described in the work of Coghill (**13**) would not apply where the sensori-motor organization is complete. It is believed that an explanation based upon hormonal activity can be advanced which will fit the facts presented in this study.

The problem of just what the nature of hormonal action is has been a knotty and much discussed one. In a review article, Lashley (**21**) examines and evaluates the evidence bearing upon this problem. He asks (p. 459), "Does the hormone stimulate the growth or formation of new nervous connections . . .?" and concluded, from evidence similar to that presented in this paper, that neural connections are already laid down and the hormone is only an activator. He then raises the question (p. 460), "Does the hormone act merely by increasing the general excitability of the organism?" and concludes that hormones act too specifically as shown by cases of sex reversal, etc., for this to be true. He points out that hormones are not likely to act by causing specific changes in organs as testes, vaginal mucosa, mammae, etc., because removal of the reproductive system results in normal sexual responses when hormones are administered. Lashley then comments (p. 462), "There remains only the last alternative, that the hormones act upon the central nervous system to increase the excitability of the sensori-motor mechanisms specifically involved in the instinctive activity." He considers this last interpretation to be plausible. Seward (**26**) also believes the evidence points to direct hormonal action upon the central nervous system.

Two general conclusions are found in the studies cited in this paper and the studies evaluated by Lashley. (1) Hormones act upon established nervous organization, and (2) there exists a threshold for the activation of an instinctive pattern which relates to the amount of hormone present. The proposed interpretation would assume that different thresholds exist requiring varying amounts of a given hormone, for exciting portions of the sensori-motor mechanism controlling leg-elevation behavior. Large amounts of testosterone, for example, would thus activate the entire leg-elevation pattern, while lesser amounts would activate only a part of it. This may be summarized as follows:

X amount of testosterone crosses threshold I, activating the sensori-motor mechanism responsible for the gross torsion movement of the first stage of leg-elevation; X + Y amount of testosterone crosses thresholds I and II, activating the sensori-motor mechanisms which produce both torsion movement and leg-elevation articulated at the hip; X + Y + Z amount of testosterone crosses thresholds I, II, and III, producing the torsion movement, leg-elevation articulated at the hip, and crooking of the leg.

The fact that a maturing male dog secretes gradually increasing amounts of male sex hormones would fit in with this hypothesis. That is, as the animal matured, sufficient testosterone would be produced to activate sensori-motor mechanism I, producing the torsion movement of the back. Larger amounts of testosterone secreted later would progressively cross other thresholds and activate other mechanisms, producing more specific behavior. This hypothesis would likewise explain why lesser amounts of testosterone produced only a partially individuated leg-elevation in animal 5a. It would also explain why castrated animal 3a was observed to revert from a complete leg elevation to a partially individuated leg-elevation and then to the puppy posture after testosterone injections were halted.

Summary and Conclusions

The micturition behavior of 22 dogs, 16 males and six females, was studied under various experimental conditions. Littermate controls were employed in determining the effect of castration, control of practice by delay in a sling and treadmill apparatus, injection of male or female sex hormones in experimental animals, and control of olfaction. Direct observation and motion pictures were used in recording the results of these experimental conditions, as well as the development of the normal micturition pattern.

It was found that there was little distinction in the urination posture of young male or female puppies, both sexes employing a squatting position. With increasing age, males tended to stand more erect when urinating and also to urinate more frequently but less copiously than females. Normal females did not at anytime elevate the leg during urination. Normal males elevated the leg when urinating as early as 19 weeks of age and as late as 43 weeks in the group studied.

It was found that development of locomotion followed a cephalo-caudal direction. Leg-elevation behavior in males was not observed until several months after locomotor development was relatively complete and the animals walked in a digitograde manner. The development of leg-elevation was found to be sequential and to follow a proximo-distal direction. Three main stages in leg-elevation were observed: a gross torsion movement in which the leg was elevated only an inch or two from the ground; a higher leg-elevation articulated at the hip in which the leg was straight, a complete leg-elevation articulated at the hip which included a crooking of the leg. In some animals a further individuation was noted in the splaying of the toes of the paw.

It was observed that normal adult male dogs regressed to the puppy posture of urination when subjected to what appeared to be fear-arousing stimuli. Practice in leg-elevation was controlled by placing a young puppy in a sling and treadmill apparatus which prevented leg-elevation. Although confined continuously in this apparatus for four weeks before and five weeks after his control littermates exhibited leg-elevation behavior, this 'delayed' animal revealed a completely individuated leg-elevation posture shortly after being released from the delay cage. Castrated animals did not reveal leg-elevation behavior even several months after their control littermates did. When injections of testosterone were administered to castrated males, the animals elevated the leg when urinating a few days afterward. Halting the testosterone treatment resulted in a reversion to the puppy urination posture. This was repeated four times in one animal, resulting alternately in leg-elevation and a reversion to the puppy stance during urination. A control over olfaction in one dog did not interfere with the emergence of leg-elevation behavior.

Female sex hormones were injected in large quantities to normal adult males. Instead of disrupting leg-elevation behavior, this treatment initially caused a marked increase in the frequency of leg-elevations, at times more than 100 in an hour. Subsequent smaller injections of estrogens resulted in a disruption of the pattern and a reversion to the puppy urination posture. Cessation of the hormone injections was followed by a revival of normal adult leg-elevation. Male sex hormones injected in female dogs resulted in frequent male copulatory behavior and more frequent urination. However, the adult male leg-elevation pattern did not appear in the females thus treated. Testosterone injected in a young puppy resulted in leg-elevation at eight weeks of age, two months earlier than his control littermates. Partial individuation of the leg-elevation pattern occurred when smaller doses of testosterone were administered to this immature animal. It was also observed that some dogs exhibit a preference when elevating the leg during urination. Evidence from various studies indicates that the neural pattern responsible for copulatory activity in rats is present at birth or shortly afterward. Other evidence indicates that there is a threshold which is lowered or crossed by adequate amounts of the appropriate sex hormone when this neural organization is activated. In order to explain how individuation in canine leg-elevation behavior could occur if the sensori-motor mechanism responsible is present at birth, a hypothesis is advanced which makes use of data from this investigation and other investigations of sex-differentiated behavior. This hypothesis assumes that the sensori-motor mechanism activated by

hormones has several thresholds which when crossed activate portions of the leg-elevation pattern. Thus X amount of testosterone, for example, would cross threshold I and result in the first stage, the gross torsion movement, of leg-elevation. X + Y amount of testosterone would cross thresholds I and II, activating the sensori-motor mechanisms which effect the gross torsion movement and leg-elevation articulated at the hip. X + Y + Z amount of testosterone would cross the thresholds of sensori-motor mechanisms I, II, and III, producing the complete leg-elevation, including crooking the leg.

The data secured from this study are believed to merit the following conclusions:

1. Leg-elevation of adult male dogs during urination is unlearned.

2. A cephalo-caudal direction of development in locomotion precedes leg-elevation in adult male dogs. The leg-elevation pattern follows a proximo-distal direction of development. This pattern is individuated, progressing through readily discernable stages from gross to specific activity.

3. The presence of sex hormones such as testosterone is directly related to the emergence of the leg-elevation pattern in the male dog.

4. Leg-elevation behavior in adult males can be disrupted by treatment with certain female sex hormones.

5. Some dogs reveal a preference as to elevating the right or left leg, at least during the first nine months of life.

(Manuscript received March 4, 1944)

Bibliography

1. Allen, E. (editor) *Sex and internal secretions.* Baltimore: Williams and Wilkins, 1939.
2. Anderson, O. D. *The endocrine basis for differences in form and behavior.* Philadelphia: Wistar Institute, 1941.
3. Ball, J. Sex activity of castrated male rats increased by estrin administration. *J. comp. Psychol.*, 1937, **24**, 135–144.
4. Ball, J. Male and female mating behavior in prepubertally castrated male rats receiving estrogens. *J. comp. Psychol.*, 1939, **28**, 273–283.
5. Ball, J. The effect of testosterone on the sex behavior of female rats. *J. comp. Psychol.*, 1940, **29**, 151–165.
6. Beach, F. A. Sex reversals in the mating pattern of the rat. *J. genet. Psychol.*, 1938, **53**, 329–334.
7. Beach, F. A. Central nervous mechanisms involved in the reproductive behavior of vertebrates. *Psychol. Bull.*, 1942, **39**, 200–226.
8. Beach, F. A. Execution of the complete masculine copulatory pattern by sexually receptive female rats. *J. genet. Psychol.*, 1942, **60**, 137–141.
9. Best, C. H., & Taylor, N. B. *The physiological basis of medical practice.* Baltimore: Williams and Wilkins, 1939.
10. Brown-Sequard, C. Comptes Rendus de la Soc. Biol. de France, 1889.
11. Cannon, W. B. *Animals in research.* Chicago: Amer. Med. Ass., 1936.
12. Carmichael, L. The development of behavior in vertebrates experimentally removed from the influence of external stimulation. *Psychol. Rev.*, 1926, **33**, 51–58.
13. Coghill, G. E. *Anatomy and the problem of behavior.* London: Cambridge University Press, 1929.

14. Combemale, P. Sur la psycho-physiologie du chien deprivé du testicle. *Compt. Rend. Soc. Biol.*, 1929, **101**, 1133–1161.
15. Dennis, W. The effect of restricted practice upon the reaching, sitting, and standing of two infants. *J. genet. Psychol.*, 1935, **47**, 17–32.
16. Engel, P. The psychical activity of male and female sex hormones of horse urine. *Endocrinol.*, 1941, **28**, 849–850.
17. Hilgard, J. R. Learning and maturation in pre-school children. *J. genet. Psychol.*, 1932, **41**, 36–56.
18. Hoskins, R. G. *Endocrinology*. New York: Norton, 1941.
19. Kudanoff, D. Die Wirkung der Frühkastration auf die Ausbildung von Nervenendingen in den Genitalorganen der Saugetiere. *Z. Zellforsch. Mik. Anat.*, 1930, **10**, 427–455.
20. Kunde, M. M., D'Amour, F. E., Carlson, A. J., & Gustafson, R. G. The effect of estrin injections on the basal metabolism, uterine endometrium, lactation, mating, and maternal instincts in the adult dog. *Amer. J. Physiol.*, 1930, **95**, 630–640.
21. Lashley, K. S. Experimental analysis of instinctive behavior. *Psychol. Rev.*, 1938, **45**, 445–471.
22. Maier, N. R. F., & Schnierla, T. C. *Principles of animal psychology*. New York: McGraw-Hill, 1935.
23. Morrell, J. A., & Hart, G. W. Studies on stilbestrol: III. Some effects of continuous injections of stilbestrol in normal and castrate adult rats. *Endocrinol.*, 1941, **29**, 995–1002.
24. Noble, G. K., & Zitrin, A. Induction of mating behavior in male and female chicks following injection of sex hormones. *Endocrinol.*, 1942, **30**, 327–334.
25. Patton, J. W. Fright disease an avitaminosis. *Veterinary Med.*, 1939, **34**, 372–381.
26. Seward, J. P. Studies on the reproductive activities of the guinea pig: III. The effect of androgenic hormone on the sex drive in males and females. *J. comp. Psychol.*, 1940, **30**, 435–449.
27. Seward, J. P. The hormonal induction of behavior. *Psychol. Rev.*, 1941, **48**, 302–315.
28. Seward, J. P., & Seward, G. H. Studies on the reproductive activities of the guinea pig: I. Factors in maternal behavior. *J. comp. Psychol.*, 1940, **29**, 1–24.
29. Shepard, J. F., & Breed, F. S. Maturation and use in the development of an instinct. *J. anim. Behav.*, 1913, **3**, 274–285.
30. Steinach, E. Geschlechtstrieb und echt sekundäre Geschlechtsmerkmale als Folge der Innersekretorischen Funktion der Keimdrusen. *Zbl. Physiol.*, 1910, bd. I.
31. Stone, C. P. A note on "feminine" behavior in adult male rats. *Amer. J. Physiol.*, 1924, **68**, 39–41.
32. Stone, C. P. Delay in the awakening of copulatory ability in the male albino rat incurred by defective diets. *J. comp. Psychol.*, 1924, **4**, 195–224.
33. Stone, C. P. The rentention of copulatory ability in male rats following castration. *J. comp. Psychol.*, 1927, **7**, 369–387.
34. Stone, C. P. Experimental studies of two important factors underlying masculine sex behavior: the nervous system and the internal secretion of the testis. *J. exp. Psychol.*, 1938, **26**, 217–236.
35. Stone, C. P. Copulatory activity in adult male rats following castration and injections of testosterone propionate. *Endocrinol.*, 1939, **24**, 165–174.
36. Stone, C. P. Counteracting the retarding effects of inanition on the awakening of copulatory ability in male rats by testosterone propionate. *J. comp. Psychol.*, 1942, **33**, 97–105.
37. Troy, W. A. Sulphapyridine in the prophylaxis and treatment of distemper in laboratory animals. *Univ. Mich. Hosp. Bull.*, 1941, **7**, 62–64.

HYPNOTIC RECALL OF MATERIAL LEARNED UNDER ANXIETY- AND NON-ANXIETY-PRODUCING CONDITIONS [1]

BY BERNARD G. ROSENTHAL

Princeton University

Introduction

It has been claimed that the state of hypnosis has a considerable capacity for increasing recall. Among the powers attributed to it are the ability to effect recall for forgotten childhood experiences, to remove traumatic amnesias, and to reproduce in more complete detail than in the waking state the most casual observations and even superficially memorized material.

Although many of these claims invite suspicion because of defects in the investigations and because of the uncontrolled clinical observations upon which they are based, there is sufficient reliable evidence (**5, 10, 12, 15**) to indicate that hypnotic hypermnesia may occur under certain circumstances.

This investigation was undertaken to help clarify the nature of hypnotic hypermnesia. More specifically, the experiments were formulated to determine systematically the relative amounts of recall of nonsense, meaningful, emotionally irritating (profane), and success-failure material under hypnosis and in the normal waking state. It was proposed to determine whether success-failure problems (reward and disparagement of answers to simulated 'intelligence test' questions under conditions of ego involvement), profane, and meaningful material show greater recall under hypnosis than under ordinary waking conditions, and how this difference compares with the recall of non-emotional, non-meaningful material under the two conditions.

Previous Investigations

Since Huse (**6**) and Mitchell (**8**) have shown that nonsense syllables were recalled no better under hypnosis than under normal waking conditions, and P. C. Young (**16, 17**) has reported the same for adjective-noun associates and casual observation of the furnishings of a room, the question has arisen as to whether recall of nonsense and innocuous material (single word associates and unimportant items)

[1] From the Psychological Laboratory of Princeton University.

is comparable to and involves the same psychological processes as recall of meaningful and emotional material.

Certainly the Freudian theory of forgetting, with its emphasis on repression of emotionally disturbing experiences, and the remembering of those which are pleasant or non-anxiety-producing, distinguishes between the recall process involved in non-emotional material (not under stress conditions) and that involved in emotion-provoking situations (success-failure items under conditions of anxiety or tension). Indeed, it might even be expected that meaningful material, which by its very nature may embody emotional factors, would conform more to the kind of recall shown by emotion-provoking than by non-emotion-provoking material.

Moreover, Bartlett's (1) conceptualization of remembering as the organized reconstruction of past experience from the emotional 'attitude' or meaningful schema which is retained would argue for a different recall process for nonsense and meaningful material. Whereas the latter is subject to organized meanings and hence varied associations, the nonsense material, because of its lack of context and limited associations, is less likely to be as readily recalled as meaningful material.

Thus, from Freud's and Bartlett's conception of the memory process it would appear to be unjustified to generalize from recall of non-emotional nonsense syllables to recall of meaningful and emotional material. Whether the interpersonal relationship underlying hypnosis embodies certain psychological factors instrumental in enhancing recall of meaningful and emotional material, but not of nonsense or innocuous material, is a question to be determined experimentally.

In support of the distinction between recall of meaningful and nonsense materials under hypnosis is the study by Stalnaker and Riddle (12), who found hypermnesia under hypnosis for poems, and the work of White, Fox, and Harris (15), who showed that while nonsense material does not show hypermnesia under hypnosis, poetry and motion picture scenes do. Similarly, Morton Prince (10) reported a controlled investigation in which two of his hypnotic subjects were able to recall, almost verbatim, letters written some time previously, but fell far below this achievement in the waking state. P. C. Young (17) likewise reports that, under controlled conditions, hypermnesia for events of childhood was clearly obtained in one subject and to a lesser degree in another.

While these investigations would indicate that the recall process for meaningful as opposed to nonsense material is different under normal waking conditions from under hypnosis, there has never been any systematic appraisal of the relation between recall of emotion-

provocative material under hypnosis as compared to both meaningful and nonsense material. In view of the fact that many clinical reports indicate hypnotic hypermnesia for emotionally toned 'lost memories,' and in view of the theory of repression which implies recovery of such 'lost memories' under certain emotional circumstances, such an experimental appraisal would appear to be needed. Moreover, the results would be significant for a theory of interpersonal relations underlying hypnosis, for by ascertaining under what experimental conditions hypnotic hypermnesia occurs, if at all, it might be determined what factors are peculiar to the hypnotic state that enable it to enhance recall for certain kinds of material rather than others, and to that extent throw light on the hypnotic relationship.

Procedure

To determine the relative recall of varying materials under normal waking and hypnotic conditions, seven experiments were devised, three involving nonsense material, two containing poetry material, and one each with profane-innocuous words, and success-failure tasks. The reasons for using this number of experiments were: (1) to compare possible variations in the recall of emotion-provocative material in meaningful and nonsense contexts; (2) to compare nonsense material recall with meaningful recall, and each of these with the recall of emotional-provocative material; and (3) to determine whether there is any difference in waking recall for successful as opposed to failing items, and whether the recall for either of them can be improved under hypnosis.

The *S*s were 13 Princeton undergraduates from 19 to 22 years of age, ranging in susceptibility to hypnosis from medium to deep on the Davis-Husband scale. In all experiments, the *S*s first performed the necessary activities: memorization, tasks, etc.; then after an interval of time or immediately afterwards, depending on the experiment, they recalled the material in the waking state. Immediately after the first recall, the control group had a second recall in the waking state, while the experimental group had its second recall in the hypnotic state. Each *S* participated in each of the seven experiments twice: once as a member of the control group and once in the experimental group. Therefore, each *S* acted as his own control. Hence the procedure for each of the 13 *S*s when they were the control group was: learning material, recalling it in the waking state, recalling it again in the waking state. The procedure for the same 13 *S*s as members of the experimental group was: learning similar but not identical material, recalling it in the waking state, recalling it again in the hypnotic state. The directions for recall were precisely the same in the waking and hypnotic states of each experiment.

Whether there was a lower threshold for recall under hypnosis than in the normal state would then be determined by noting whether any increase in recall in the hypnotic session over the previous waking session (experimental group) was significantly greater than any increase in recall in the control group's second waking session over its first. By this method the effect of hypnotic recall after waking recall would be compared with the effect of waking recall after waking recall. Hypnotic hypermnesia could then be tested by noting the difference between the experimental and control group differences between first and second recall.

Since each *S* served as his own control, precautions had to be taken to insure against familiarity with material and experimental setting as well as to maintain motivation at a high level. This was accomplished by allowing at least 10 days between the control and experimental session of each experiment, and by having half the group first participate as the control group, after which they acted as the experimental group, and reversing the order for the other half.

In order to control effects of material, position, and specific interest of items, the following precautions were observed: (1) Since similar but not identical material was used for control and experimental groups in each experiment, it was necessary to control differences in material between these groups which might affect recall. Therefore, one-half of the experimental group was given the same material which one-half of the control group was given, while the other half was given

identical material with the other half of the control group. Thus, while Subject I was given one task when a member of the experimental group and another when a member of the control group, Subject II, when in the experimental group, was given the same task which Subject I had in the control group, and the same task in the control group as Subject I had in the experimental group; and so on for the other *S*s. (2) Within each group the *S*s who were given identical material to be learned (e.g., one-half the *S*s in each group) were split into two sections. Although the material given to both sections was the same, the order of items differed in each, so that those items which constituted the first half of the series in one section became the last half in the other, the situation being reversed for the other sections. Special care was taken to randomize the items within each section for each *S* and to make sure the items appearing at beginning and end of the material for one *S* would be placed near the middle for another. This precaution helped control the effect of position on recall. (3) Since some of the experiments involved reward for some items and punishment for others, it was necessary to avoid designating the same item as success or failure consistently. As far as possible, the items which were indicated as successful for one *S* were indicated as failure for the other.

The first two precautions were employed in Experiments II and VI. All were used in Experiments III and VII. Modifications of them were used in Experiments IV and V which contained poetry material.

Experiment I.

The memory material consisted of three sets of nine items, each item consisting of a pair of three letter nonsense syllables. These were memorized in one session. The method was as follows: a pack of cards was handed to the *S*s, on each of which was printed a syllable which the *S* pronounced and to which the *E* gave an associate. Each set was run through three times, whereupon the cards were surrendered to *E* and *E* pronounced the first syllable and *S* gave the paired associate, *E* prompting *S* when an error was made. Recall took place 24 hours later, *E* calling the first syllable and *S* responding with the associate. The second recall, which took place immediately after the first, was in the waking state for the control group and in the hypnotic state for the experimental group. The same experiment was performed ten days later with each *S* but with different nonsense material.

RESULTS:

Table I gives the results for the nonsense materials. Rows 1 and 2 respectively show the mean number of nonsense syllables recalled in the first and second recall sessions. In this table, the only recall which took place under hypnosis was the second recall in the experimental group.

TABLE I

SHOWING THE MEAN NUMBER OF NONSENSE SYLLABLES RECALLED IN EXPERIMENT I AND THE LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS, OBTAINED BY THE USE OF THE *t*-TEST FOR THE SIGNIFICANCE OF A DIFFERENCE BETWEEN MEANS OF RELATED MEASURES

(The level of confidence was obtained in the same manner for the succeeding tables)

Row		Experimental	Control
1	Recall I. Mean no. of syllables recalled	8.76	8.39
2	Recall II. Mean no. of syllables recalled	8.84	8.57
3	L of C * of difference between Recalls I and II	70%	50%
4	L of C of difference between Experimental and Control groups, Recall I	L E 20%	
5	L of C of difference between Experimental and Control differences of Recall I and Recall II	80%	

* L of C = Level of confidence.

The *t*-test for the significance of a difference between the means of related measures was used to determine the significance of the difference between recalls in each of the experimental and control sessions. It was also used to determine the significance of the difference between differences, i.e., whether the improvement of recall two over recall one was significantly greater in the experimental group than the increase of recall two over recall one in the control group. An improvement in recall under hypnosis over the previous waking recall which was significantly greater than any increase in recall of the second waking state over the first in the control group, would indicate hypermnesia under hypnosis. Finally, the significance of differences between the first recalls of the control and experimental groups was computed in order to determine whether any significant differences that do occur in the second recall between experimental and control groups possibly result from a difference in primary recall between these two groups.

Consulting the table, we find the data indicate that: (1) The difference between the first and second recall in both groups is not significant (Row 3); (2) similarly, the difference between experimental and control group differences of Recall I and Recall II is not significant (Row 5); (3) there are no significant differences in primary recall (Row 4). Evidently there is no hypermnesia under hypnosis for nonsense syllables.

Since one of the important objects of this investigation was to determine whether nonsense syllables learned in anxiety-producing situations would be subject to hypnotic hypermnesia, it was decided to repeat Experiment I, but under stress conditions which would make the *S*s feel anxious and react as if real success and failure were involved.

Therefore each *S* was motivated by the incentive of success and failure on lists of nonsense syllables which he was told constituted tests of his intelligence. It was hoped that under these conditions differential recall could be obtained, which could then be tested for hypnotic hypermnesia. A preliminary experiment consisted of presenting lists of five nonsense syllables each, by means of a memory drum, each list being exposed twice and the *S* being asked to recall at the end of the second exposure. The *S* was then told either that he had failed or had succeeded, and was given every reason to believe this was an index of his mental ability. After all the lists were gone through, *S* was asked to recall as many items as possible. Invariably, protocols of distress and anxiety feelings were obtained, but the initial amount of recall was so small (5 percent of the material) and so spottily distributed through the lists that even if there were repression, it could not be measured.

Because of this limited recall (owing to non-emotional factors, such as passing from one list to another quickly, and associative inhibition resulting from the similarity of material between lists) there was no adequate amount of, nor sufficiently clearly defined, context with which to identify success or failure.

This preliminary experiment may be considered an exploratory attempt to develop a method by which nonsense syllables, learned under stress conditions, can be 'repressed,' and hence to test the assumption of hypnotic hypermnesia for repressed nonsense syllables. That the experiment, because of methodological defects, did not properly test this assumption is evident. It did, however, have a secondary value, since, through analysis of its defects, it was possible to formulate the experiments by which a test of this assumption could be made.

A new method, therefore, was devised, which, while giving negative results for hypnotic hypermnesia under non-anxiety-producing conditions (in support of previous investigations), would produce under conditions of anxiety those experiences of success and failure that were associated by *S* with the items designated success and failure, respectively, and were recalled as such. If hypnotic hypermnesia were then obtained under such anxiety conditions, it could not be ascribed to differences in experimental procedure between previous investigations and this one, since the same method which might give results indicating hypnotic hypermnesia under emotional producing conditions, did not give such results when these conditions were eliminated. Experiment II, described immediately below, served as a check on previous studies of hypnotic hypermnesia for nonsense material while employing an entirely different experimental approach. Experiment III, identical with Experiment II except for success-failure incentives, provided the test of hypnotic hypermnesia for nonsense syllables in an anxiety-producing context. Hence, since Experiment II was comparable to Experiment III in every way except emotional context, any difference between the results of Experiment III and those of previous studies would be attributable to emotional factors.

Experiment II.

The material for this experiment consisted of 16 lists of nonsense syllables, five in each list, with innocuous meaningful words such as *grass*, *house*, etc., interspersed at random in each list. The lists were kept as distinct from one another as possible so far as nonsense similarities were concerned. The innocuous meaningful words were inserted in order to differentiate these lists still further. These syllables and words were exposed for one sec. by a memory drum, and each list was exposed twice in this manner, the *S*s being prompted automatically on the second exposure. At the end of the second exposure, they were asked to recall as much as possible. After all 16 lists had been thus exposed, the *S* was given 15 min. of rest, and was instructed not to think of the previously exposed material. After this, he was instructed to recall as many meaningful words as

he could. Thus, the criterion of recall was the number of meaningful words, interspersed at random in each list, which were remembered. The second recall, which took place immediately after the first, was in the waking state for the control group and in the hypnotic state for the experimental group.

At the beginning of the experiment, the *S* was given the following verbal directions: "We are interested in this experiment in determining generalized rates of retention for most people in order to establish laws about the relation between learning and remembering. Therefore, this experiment is not a test that will determine your abilities. All it does is to indicate what the processes of remembering are. We are only interested in what groups do."

RESULTS:

Table II gives the results for the 16 nonsense lists with meaningful associates. The score was the number of meaningful words recalled.

TABLE II

SHOWING THE MEAN NUMBER OF WORDS RECALLED IN EXPERIMENT II AND THE LEVEL OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS

Row		Experimental	Control
1	Recall I. Mean no. of words recalled	9.47	8.92
2	Recall II. Mean no. of words recalled	9.69	9.22
3	L of C * of difference between Recalls I and II	80%	70%
4	L of C of difference between Experimental and Control groups, Recall I	20%	

* L of C = Level of confidence.

There was no significant difference in initial recall between the groups (Row 4), nor was there a significant difference between recalls I and II for either group (Row 3). These results are comparable to those of Experiment I, and it is clear that there is no hypermnesia even when a different method from that of previous investigators is used and when meaningful words are added. Insofar as this experiment shows no hypermnesia and confirms the results of previous investigators, it indicates the identity between psychological processes of recall working here and in traditional nonsense material such as that used by Huse.

Experiment III.

The same conditions prevailed as in Experiment II except that the directions were different. Each *S* was read the following: "This is a test of your ability to learn material within a limited amount of time. Since this material is in no way dependent on previous knowledge, it is a test of innate intelligence. The number of words remembered determines whether you pass or not. After each list, I will tell you whether you passed or failed. We have standardized criteria for different materials, so that while you may learn more on one test than on another, you may fail, since the material was actually easier, and you should have learned more.[2] Remember this is an intelligence test comparable with your college entrance tests, and I will tell you whether you

[2] It was further explained that a possible reason for failing a test on which more was learned than on a test which the *S* had been told was successful was that the material was easier on the 'failure' test and more should have been learned in order to reach the level of achievement of the task designated 'success.'

flunked or not." In the second session of the experiment, similar directions were given with the added injunction: "We are going to give you a chance to improve since your score was so bad last time."

The only difference between Experiments II and III was the directions given to the *S*s, which were calculated to produce emotional tension. That this situation was anxiety-producing was evidenced by the worry shown by one *S* for a day afterwards, by the blanched faces of many of the *S*s during the experiment, by the fact that one boy reported he sought for consolation from the distress by seeking help from friends, and finally, by the fact that two men, despite warnings that the experiment involved psychic tension and that they entered it on these conditions, none the less wanted to drop out. Similar evidence of anxiety in lesser degree was exhibited by all the *S*s. The situation was a minor trauma and had to that extent resemblance to life experience.

In order to keep these induced tension effects constant throughout the series of success-failure experiments, it was necessary to resort to more drastic motivational policies in the latter sessions (described below), and also to the expedient of separating success-failure tests by periods of at least two weeks between each test for each *S*. That this method was effective is indicated by the fact that the *S*s showed the same behavior as was exhibited in the first success-failure test throughout the other success-failure tests.

RESULTS:

The results are given in Table III. The letters S and N stand respectively for the average number of non-anxiety-provoking items,

TABLE III

SHOWING THE MEAN NUMBER OF SUCCESSFUL (S) AND FAILING (N) WORDS RECALLED IN EXPERIMENT III AND THE LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS

Row		Experimental		Control	
		S	N	S	N
1	Recall I. Mean no. of words recalled	4.9	3.3	5.0	3.1
2	Recall II. Mean no. of words recalled	5.0	4.8	5.2	3.3
3	L of C * of difference between Recalls I and II	80%	2%	70%	70%
4	L of C of difference between S and N, Recall I	1%		1%	
5	L of C of difference between S and N, Recall II	80%		1%	
6	L of C of difference between Experimental total and Control total, Recall I	30%			
7	L of C of difference between Experimental and Control differences of S in Recalls I and II	60%			
8	L of C of difference between Experimental and Control differences of N in Recalls I and II	1%			
9	L of C of difference between Experimental and Control differences of total Recall I and total Recall II	2%			

* L of C = Level of confidence.

and for the average number of anxiety-provoking items recalled in each session. The significance of the difference between S and N is computed for each session to determine whether any actual repression effect has occurred, i.e., whether anxiety-producing items are recalled less well than approved or successful items. The significance of the difference between S items recalled in the first and second recall sessions is computed for both experimental and control groups to determine whether there is any significant increase in S items recalled

under hypnosis and in the second waking state. The same is done for the N items in the first and second recall sessions for the same reason.

From a study of Table III it is clear that both the experimental and control groups show a significant difference between S and N in Recall I (Row 4). It will be noted that this difference between S and N is practically the same for the experimental and control groups, and since there is no significant difference between the experimental and control groups in the total number of items recalled in the initial recall session (Row 6), the difference between S and N may be interpreted as a function of the affective variable. Furthermore, from an analysis of the difference between the S items recalled in Recall Sessions I and II, it is clear that no significant increase in recall of successful items has been made (Row 3). However, the difference between the N items in Recall Sessions I and II is significant, indicating that the increase in items in Recall II has been caused solely by recalling more N items (Row 3). Apparently hypnosis does enhance recall, but only recall of negative, 'failing,' items. A confirmation of this finding is to be seen in the results of the control group, where, although there is a significant difference between S and N in Recall I, the second waking recall does not produce hypermnesia for either S or N items, as shown by the fact that the difference between the S items in Recall I and II and the difference between the N items in Recall I and II are not significant (Row 3). Clearly, though there is differential recall, there is no hypermnesia in the second recall in the waking state for either S or N items.

From a comparison of the difference between differences of the S and N items (separately considered) in their respective first and second recalls, it will be seen that, whereas the difference between the N items in the experimental group's first recall session and its second recall session (under hypnosis) is significantly greater than the difference between the N items in the control group's first and second recall sessions, there is no significant difference between experimental and control group differences of S items in Recall I and Recall II (Rows 7 and 8). The significance of the difference between differences of the total S and N items is at the 2 percent level (Row 9).

To summarize: (1) While hypnotic and normal waking recall are equally effective for S items, hypnosis alone improves recall for N items. (2) There is no change at all for N items in the control group. (3) The increase of N items in hypnosis brings them to the point where they are equal to the S items. (4) The lack of increased recall for S items in either group is similar to constancy of recall for nonsense material in Experiments I and II; whereas the increase in N items

under hypnosis contrasts with this. So that while nonsense material under no stress shows no hypermnesia under hypnosis, similar material under stress conditions does show it.

Experiment IV.

Meaningful materials in the form of poetry were prepared, along the lines of Stalnaker and Riddle (12), and White, Fox, and Harris (15), in order to test our assumption that the memory process for such material under hypnosis was different than for nonsense material, and in order to compare the effect of hypnosis on the recall of meaningful material as opposed to nonsense material learned under emotion-producing conditions.

The meaningful materials consisted of eight five-line stanzas of from 35 to 45 words each, with an average of 40 words. Four of these poems were given to the experimental, and four to the control, group. The *S* was given the poem on a card to read aloud twice, after which he recited it until one perfect repetition was made without prompting. Four poems were memorized in one session by each member of both the experimental and control groups. The poems were so distributed between the two groups that not all *S*s in the same group learned the same poems. The *E* read the first line of each poem, and hence it was not counted in the results. Recall I took place 24 hours after learning, each poem being tested once, the *S* being allowed to continue until there was a long pause or he indicated he could recall no more. Recall II, which took place immediately after Recall I, was in the waking state for the control group and in the hypnotic state for the experimental group.

RESULTS:

Table IV gives the results for this experiment. It will be seen that there was no significant difference in primary recall between the

TABLE IV

SHOWING THE MEAN NUMBER OF WORDS OF POEMS RECALLED IN EXPERIMENT IV AND THE LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS

Row		Experimental	Control
1	Recall I. Mean no. of words recalled	46.3	48.3
2	Recall II. Mean no. of words recalled	61.3	52.4
3	L of C * of difference between Recalls I and II	1%	60%
4	L of C of difference between Experimental and Control groups, Recall I	60%	
5	L of C of difference between Experimental and Control differences of Recall I and Recall II	1%	

* L of C = Level of confidence.

groups (Row 4). In Recall II there was a slight gain in total words recalled by the control group, but this gain is not significant (60 percent) (Row 3). The experimental group, however, shows a significant increase at the 1 percent level (Row 3). Thus, the hypnotic session shows hypermnesia for meaningful material. It should be noted in this connection that while the S items in Experiment III showed no increase either in the waking state or under hypnosis, meaningful material, i.e., material in a context of organized associations, and not single words, does show an increase under hypnosis but not in the waking state. Why the S items in Experi-

ment III should not show an increase under hypnosis and the meaningful material should is a question with considerable bearing on the nature of the hypnotic state.

Experiment V.

Since meaningful material gave an increase in recall under hypnosis, and success-failure nonsense material similarly showed hypnotic hypermnesia, it was argued that meaningful success-failure material should give an even greater increase. It was hoped, therefore, to devise an experimental test of this assumption which would be free of methodological defects such as associative inhibition that would obscure the nature of the results.

Ten poems of from 20 to 22 words in length were read by each *S* in both the experimental and control sessions. The poems were so distributed within the two groups that not all *S*s in the same group read the same poems. Each poem was read once out loud by the *S*, who was previously instructed that: "This will be an examination of your ability to learn meaningful material, and hence an index of your ability to study well. In this sense it is a test of the resultant of concentration, intelligence, and knowledge." As soon as the *S* had read the poem, he handed it to the *E* and was asked to recall as much as possible. One-half of his recalls were arbitrarily called failure or substandard, i.e., not coming up to the normal level. It was indicated to the *S* that since the poems were graded in material from easy to difficult, an almost completely memorized poem might be considered a failure if the material were very easy. After the verdict of success or failure had been given for each of the 10 poems, there was a 10-min. rest, and then recall. The *S*s were asked to recite as much as they could remember. At a long pause or at the *S*'s own request, the effort was discontinued. The second recall took place immediately after the first, and was under hypnosis in the experimental group.

Results:

The results are presented in Table V. It will be seen that there are no significant differences in initial recall of poems associated with

TABLE V

Showing the Mean Number of Words of Success (S) and Failure (N) Poems Recalled in Experiment V and the Levels of Significance of the Differences Between Means

Row		Experimental		Control	
		S	N	S	N
1	Recall I. Mean no. of words recalled	44.4	45.5	45.3	46.6
2	Recall II. Mean no. of words recalled	45.0	46.0	47.1	47.3
3	L of C * of difference between Recalls I and II	80%	80%	70%	70%
4	L of C of difference between S and N, Recall I	80%		80%	
5	L of C of difference between S and N, Recall II	80%		90%	
6	L of C of difference between experimental total and control total, Recall I	80%			

* L of C = Level of confidence.

success as contrasted to those designated failure in either the control or experimental group (Row 4). Also to be noted is that there is no hypermnesia for either the S or N material in either control or experimental group (Row 3). In short, the results in this experiment

are very similar to those of the preliminary experiment before Experiment II.

It should be noted that the procedure by which one poem was presented immediately after another with but one reading was not conducive to any initial learning, for there was hardly any time for the *S* to retain any material or for the poems to make any but the most cursory impression. This can clearly be seen by noting that the average initial recall was only about 45 words for both groups, giving an average of about four and one-half words per poem, or less than 20 percent of all the material available for recall. With so much associative inhibition, and with so little initial learning, it becomes clear why there was no differential recall and hypermnesia. With so little material retained, there was little chance to reveal affective forgetting, and with so speedy a reading, one poem became fused into another, so that the possibility of associating with emotional experience was lost. In other words, the memory material became so undifferentiated and blurred, that there could be no identification with the appropriate affect. That emotion was present was indicated by the protocols which revealed tension and anxiety upon the part of the *S*s.

Experiment VI.

To analyze further the emotional relationship between improvement in recall and success-failure motivation, and to compare conventionally emotionally disgusting stimuli with neutral stimuli, it was decided to compare the recall of a group of 10 profane and obscene words in the waking state and under hypnosis with the recall of a group of 10 innocuous words under the same conditions. These were taken from Flanagan (4) and Sharp's (11) lists, and were really paired associates which, when pronounced together, gave the sound and meaning of the profane word, but, when separated, appeared to be nonsense syllables, e.g., gah dam. Similarly, 10 words of non-profane content were constructed on the same principle. The words followed each other at random, and there were two buffer words at beginning and end to eliminate initial and final effects on retention. These were not counted in the scoring. The words were presented serially, the *S* pronouncing each as it appeared, until the whole list was learned. Twenty-four hours later, the first syllable was presented and the *S* was required to say the associate. The experimental and control sessions were given three weeks apart. The second recall took place immediately after the first and was under hypnosis in the experimental group.

RESULTS:

The results are presented in Table VI. Although there is some indication of a difference in initial recall between S and N, it is only at the 10 percent level of significance (Row 4). Moreover, the greater number of items recalled was the N items—the profane and obscene words. This becomes understandable, since there is no need in the mind of the *S* to refrain actively from giving the obscene words, as the relationship between *S* and *E* was not stilted or formal in the experiment. Moreover, since these words were the most conspicuous and sensational ones, and since young college men actively use and

TABLE VI

SHOWING THE MEAN NUMBER OF PROFANE (N) AND INNOCUOUS (S) WORDS RECALLED IN EXPERIMENT VI AND THE LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS

Row		Experimental		Control	
		S	N	S	N
1	Recall I. Mean no. of words recalled	7.8	8.4	7.9	8.6
2	Recall II. Mean no. of words recalled	7.8	8.5	7.9	8.7
3	L of C * of difference between Recalls I and II	90%	80%	90%	80%
4	L of C of difference between S and N, Recall I	10%		10%	
5	L of C of difference between S and N, Recall II	10%		10%	
6	L of C of difference between Experimental total and Control total, Recall I	90%			

* L of C = Level of confidence.

take pleasure in indulging in these expressions, it was in no way remarkable that there was a tendency towards a greater recall of N words. The S items being more prosaic and less interesting simply were less significant for the Ss.

It will also be seen that there is no significant change in either S or N items from first to second recall in either the control or experimental group (Row 3). On the basis of the results of Experiment III it could be expected that there would be no increase for S items, but the question arises, why should there not be increase for N items under hypnosis? In this connection it should be noted that the average recall of N items was 8.5 out of a possible 10, leaving little possibility for increase in recall. Recall was so complete initially that it included almost all the material learned, and the residue not recalled was because of normal forgetting. Also, since the N items in no way gave cause for anxiety and, indeed, since they were happily and gleefully recalled, there was no cause for repression, and hence no possibility of removing inhibitions through hypnosis. The fact that the N items stood out so conspicuously in the Ss' minds is good reason for not expecting hypermnesia.

It is to be noted that in contrast to the meaningful material of Experiment IV, there was no increase of S items. This difference might be explained by assuming that the meaningful organization or connected system of ideas found in poetry is not functioning in a single word which can have but limited associations. If hypnosis somehow facilitates the reorganization of unified associations which have lapsed in the normal state, or by assisting in what Bartlett calls the reconstruction of past experience from those schemata which are retained, we can see why it should enhance recall for poems and not for isolated words which are not present in meaningful contexts.

Experiment VII.

Since success-failure incentives had been tried with nonsense material, it was decided to apply them to concrete task material. Forty tasks were selected from various sources, including verbal and motor tests. The tasks were distributed in accordance with the precautions described previously, and were also equated for interest on a group of 10 men not participating in the experiment. The *Ss* were told that: "This is the final and best test we have, is to be used in the armed services, measures mechanical ability as well as self-control, and is an index of what a man can really do and how well he will succeed." It was then indicated to them that their score would be announced after each test and that it would be determined by speed and accuracy. Since there was a time limit, if the *E* interrupted a puzzle, this was tantamount to failure on the part of *S*. A stop-watch was kept continually in view and the injunction "there is little time left" was continually used with occasional grimaces of disapproval. Actually, it was predetermined which tests the *Ss* were to fail, and this was so arranged that one half of the group would fail on the tests that the other half passed. Although failures and successes were random, an attempt was made to adhere to an alternation of success and failure. As nearly as possible conformity to the original plan was maintained: each task was given exactly as much time as the other before the *S* was interrupted and failure was announced. Usually, when the *S* took longer on a planned successful task, the *E* would give him as much time on the subsequent failing test. It happened sometimes that the *S* threatened to complete a task that had been designated as a failure. In this case, another task which had been previously designated as successful was changed into the failure commensurate with the length of time. In cases where the *S* completed success in shorter time, we did not interrupt a subsequently designated failure task to conform to this time, but let it conform to the predetermined time. This gave an advantage to the failures and not to the successes, the former having a longer time. Altogether about 35 percent of the time relations were changed in this way, but an attempt was made to interrupt the tasks that were designated as failures at the greatest point of interest.

RESULTS:

The results are presented in Table VII. The recall scores in Rows 1 and 2 represent the mean number of failure and success tasks remembered. A study of the table reveals that both experimental and control groups show significant differences between S and N

TABLE VII

SHOWING THE MEAN NUMBER OF SUCCESSFUL (S) AND FAILING (N) TASKS RECALLED IN EXPERIMENT VII AND THE LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN THE MEANS

Row		Experimental		Control	
		S	N	S	N
1	Recall I. Mean no. of tasks recalled	7.46	5.76	7.92	5.92
2	Recall II. Mean no. of tasks recalled	7.54	7.23	8.25	6.31
3	L of C * of difference between Recalls I and II	50%	2%	40%	40%
4	L of C of difference between S and N, Recall I	1%		1%	
5	L of C of difference between S and N, Recall II	30%		1%	
6	L of C of difference between Experimental total and Control total, Recall I	5%			
7	L of C of difference between Experimental and Control differences of S in Recalls I and II	40%			
8	L of C of difference between Experimental and Control differences of N in Recalls I and II	1%			
9	L of C of difference between Experimental and Control differences of total Recall I and total Recall II	1%			

* L of C = Level of confidence.

items in Recall I (Row 4). In the experimental group, however, there is a significant increase of N items in Recall II over Recall I (Row 3) which, considered together with the constancy of S items from first to second recall, eliminates the 'repression' effect of Recall I, and leaves no significant difference between S and N in the second recall (Row 5). Once again, as in Experiment III, hypnosis does have an enhancing effect on recall, but only for negative items. The indubitable fact is thus corroborated in this experiment, that failing items are less well recalled than successful ones, and that this difference is eliminated under hypnosis, i.e., the negative items are recalled as well as the successful ones under hypnosis. That this does not occur under normal waking recall can be seen by the lack of change for either S or N items from the first to the second recall in the control group (Rows 4 and 5). Here also the N items are less well recalled than the S items, but they remain less well recalled in the second waking recall in contrast to their increase under hypnosis. These differences are confirmed in the rows showing the differences between differences, where it can be seen that the increase of N items in the experimental group is significantly greater than in the control group (Row 8); so significant indeed, that it makes possible the entire difference between experimental and control differences of total S and N items in Recall I and Recall II to be at the 1 percent level of significance (Row 9) despite no significant difference between S differences (Row 7).

Once more, as in Experiment III, the results indicate that the hypnotic and normal waking states are equally effective for S items, while hypnosis alone enhances recall for 'failure' items.

Discussion

How can these results be explained? It has been suggested that hypnosis benefits recall by decreasing the effects of retroactive inhibition. If this is true, it would have to be shown that the meaningful material and the failing items in the anxiety-producing task and nonsense syllable experiments suffered more retroactive inhibition than the nonsense material learned in non-stress situations and the rewarded items in the anxiety-provoking nonsense and task series.

In the attempt to explain hypnotic hypermnesia for meaningful material as opposed to lack of hypermnesia for nonsense material, this hypothesis encounters insuperable obstacles. Since both materials were recalled 24 hours after learning, it is difficult to understand, on the basis of this theory, why there should be a lowered recall threshold for one kind of material rather than the other. Indeed, the nonsense

material with its lack of system and cohesion and its confusing similarities, is more subject to mutual interference than poetry which has a distinct structure and an organized meaning. Also, the 24-hour interval between learning and recall might cause more inhibition for disconnected nonsense material than for meaningful material. Welborn and English (**13**) report that Radosawljewitsch found 79 percent of the original poetry learned was retained after one day while Ebbinghaus found only 34 percent of the original nonsense material was recalled after the same period. In this connection it is interesting to note that Newman (**9**) has found that plots of stories are exempt from retroactive inhibition, while superfluous details suffer it considerably. And since nonsense material cannot be considered as comparable to plots in unity and structure while poetry can, there would appear to be more retroactive inhibition for nonsense material, and hence, according to this theory, it should show hypnotic hypermnesia. Also against this hypothesis is the fact that there was no better recall under hypnosis for those nonsense materials which were recalled 24 hours after learning than those recalled immediately after learning. Certainly there would be more inhibition 24 hours after learning than immediately after. But since there was no hypnotic hypermnesia in either case, hypnosis could not have any effect on retroactive inhibition. Finally, Mitchell (**8**) has shown that material which has suffered a considerable amount of retroactive inhibition is recovered no better in the trance than in the waking state.

Still less tenable is the hypothesis of lessened retroactive inhibition when the hypermnesia of failing items in the stress situations is considered. There is no reason to believe that hypnosis should act selectively to reduce retroactive inhibition for negative items while not disturbing it for the positive ones. Moreover, there is no hypnotic hypermnesia under identical experimental conditions when the incentives of success-failure are eliminated. Why retroactive inhibition is reduced in one case and not in the other when the only variable is anxiety-producing incentives is not clear. In the light of these considerations, we may dispense with the hypothesis of retroactive inhibition.

Hull (**5**) has suggested that hypnosis might improve memory by lowering the threshold for recall on some physiological basis. So far as explaining the difference between hypnotic recall for nonsense and meaningful material, this suggestion seems improbable, since only the latter showed hypnotic hypermnesia, although both materials were recalled 24 hours after learning. It is not clear from this theory why the recall threshold, conceived as a physiological process, should be differentially lowered, since the only known variable which

could hypothetically influence its functioning, namely, time, was held constant. So far as explaining hypermnesia for the anxiety-producing material, it is not clear why the threshold for negative items should be lowered while the one for positive items is not. Moreover, how explain the fact that there was no such lowering of threshold when the material which gave hypermnesia when learned under stress conditions did not show hypermnesia when learned under non-stress conditions? Unless one postulates a special discriminating agent in hypnosis which selectively lowers the trace threshold for one kind of recall and not for another, it is difficult to reconcile this theory with the facts. But if one does permit such a qualification, one is faced with the problem of explaining why this selective lowering occurs under one set of conditions and not another, and what characteristics of the hypnotic state enable it to enhance recall under these conditions.

In lieu of these suggestions it is proposed here, along with White, Harris, and Fox (**15**), that the reason for hypnotic hypermnesia lies in the relaxed calm and freedom from anxiety that characterize the hypnotic state. Under these conditions, the meaningful material flows together and takes proper proportion, or, as Bartlett indicates, is creatively reconstructed, unhampered by the overstrenuous tension of trying to remember that characterizes the waking state. Such sustained effort to recall with the resulting emphasis on certain parts of the material rather than others prevents the spontaneous reconstruction Bartlett believes is the essence of remembering. The material suffers a selection owing to the tension which the *S* generates in his efforts to remember, and emotional blocks arise to inhibit complete recall. But a state of relaxation presupposes a lack of tension and a minimum of volitionally sustained effort and hence tends to eliminate distortion and incompleteness from remembering.

The characteristic relaxation which enhances recall under hypnosis also improves it in the hypnogogic state and free association. On the analyst's couch, the relaxed calm is conducive to a flow of associations which recovers the memories intact or reconstructs them in their proper form. The same kind of relaxation occurs in that half-awake state when remote occurrences will come into the mind spontaneously. In this connection, Morton Prince reported a series of experiments in which memory was considerably enhanced by the techniques of crystal gazing and automatic writing. The common characteristic of these techniques of free association, of the hypnogogic state, and of hypnosis is relaxation.

From this point of view, it should be clear why nonsense syllables show no hypnotic hypermnesia and meaningful materials do. For isolated nonsense words lacking any organized context or varied

associations will not show enhanced recall in a relaxed state simply because the disconnected, disparate character of nonsense material precludes the spontaneous flowing together of meaningful memories that relaxation in hypnosis facilitates. Indeed, the rigid connection of paired associates, since it lacks the contextual structure and unitary form of poetry, would not suffer diminution of recall in a state characterized by concentration and strenuous effort. In such a state there would be a search for one specific associate, one and only one right nonsense syllable, and volitionally sustained attention could not possibly overemphasize one phase of the material to the neglect of the other, or distort the proper proportion of meaning as it does for poetry.

The same suggestion can account for the recall of the 'failing' items under hypnosis. If it is assumed that these items are not recalled as well as successful items because recall of the former involves anxiety through reminder of failure (since the *S* is alert and sensitive to criticism in a situation where he was told that to do poorly was a sign of inferior ability) it is reasonable to expect that many *Ss* [3] should remember *less* well those tasks that would remind them of their failure and restore in them the fear and anxiety of inferiority.

The characteristic relaxation of hypnosis, however, makes possible a lack of anxiety and insecurity, an elimination of the need to sustain confidence in one's abilities; under these conditions the need for ego enhancement is gone, and the *S* can remember his unpleasant experiences because he is free from fear of feelings of inadequacy or from criticism. Hence, the *S* recalls his failures under hypnosis because relaxation presupposes emotional indifference and a security born of the lack of need to defend the ego. Or, to put it another way, in relaxation, the ego functions are under no stress to protect themselves from *S*'s feelings of inadequacy, because the *S* has attained a feeling that his security cannot be disturbed, a feeling of confidence in the hands of the hypnotist that makes for neutralization of negative emotions. The psychological factors that are present in the hypnotic relationship—freedom from fear of criticism or from feelings of inadequacy—also account for the narrating of unpleasant experiences in free association and automatic writing.

The successful items, on the other hand, are recalled no better under hypnosis because they do not suffer repression owing to the lack of anxiety associated with them. Relaxation cannot facilitate their recall by eliminating inferiority feelings about them that never existed.

[3] Personality differences make for some variations in results.

If this is a true explanation of hypnotic hypermnesia, certain deductions for further investigation are in order. (1) It would follow that under any state of relaxation, recall should be enhanced for meaningful or emotionally disturbing material in proportion to the depth of the state of relaxation. (2) If the state of relaxation should change to one of non-relaxation, there should be an abrupt retardation of recall for meaningful or negatively disparaged material. (3) With greater time between experience and recall to allow anxiety to disappear, the failing items should be recalled as well as the successful ones. (4) If there could be produced tension under hypnosis or suspicion of the *E*, no hypermnesia should occur for failing items. (5) Those persons who are characteristically anxious should not recover anxiety-fraught material under hypnosis, since they may continue to be anxious in the hypnotic state. Thus, anxiety neurotics should not show greater recall for failing items under hypnosis, but persons with hysterical makeup, who depend greatly on others, but who are sensitive to criticism, should show the most hypermnesia.

Summary

Experiment I.

There was no hypnotic or waking hypermnesia for nonsense syllables under experimental conditions approximating those of previous investigators.

Experiment II.

There was no hypnotic or waking hypermnesia for meaningful words in nonsense syllable lists.

Experiment III.

Using the same method as in Experiment II except for the introduction of tension in the Ss through the use of success-failure incentives, it was found that there was hypnotic hypermnesia for disparaged or failing items only, while the successful items showed no hypermnesia either under hypnosis or in the waking state.

Experiment IV.

There was hypermnesia under hypnosis for the recall of poetry learned in the waking state as compared to no hypermnesia for the waking recall of the same material.

Experiment V.

Poetry learned under success-failure conditions showed no hypermnesia in either state for either 'successful' or 'failing' poems. The

amount of material and the method of learning (different from Experiment IV) resulted in an insufficient amount of recall and associative inhibition, which prevented the affective experiences from being identified with the poetry context.

Experiment VI.

Neither profane nor innocuous words showed hypermnesia under hypnosis or in the waking state. However, the profane words were recalled better than the non-profane words.

Experiment VII.

Tasks were performed under success-failure conditions. There was hypnotic hypermnesia only for description or naming of those tasks which were designated failure during performance. Successful tasks showed no hypermnesia in either state and failing tasks showed no hypermnesia in the waking state.

Conclusions

1. The results of these experiments support the clinical observations of hypnotic hypermnesia for experiences of an emotionally disturbing nature. Insofar as the success-failure situations of Experiments III and VII resemble highly charged affective situations in real life, it may be said that hypnosis does enhance recall for such 'lost memories.'

A corollary of this result is the fact that non-anxiety-producing or rewarded situations are recalled better than anxiety-producing or failure situations, and that the rewarded situations do not show any improved recall under hypnosis. This result has some bearing on the theory of repression, for hypothetically it is precisely these repressed, anxiety experiences which linger as 'lost memories' and which are susceptible to recall under proper conditions; whereas the affective experiences not involving anxiety, since they are not repressed, will have no residue which may be recovered under hypnotic conditions. The factors in the hypnotic state that make possible the recalling of existing but 'repressed' memory traces were discussed above.

2. The results from this experiment indicate that meaningful, connected material shows hypnotic hypermnesia. This is in line with the conclusions of Stalnaker and Riddle, and White, Fox, and Harris, and clinical reports including those of Prince.

On the other hand, single, innocuous words, not in an organized or meaningful context, do not show waking or hypnotic hypermnesia. The factors in the hypnotic relationship that improve the conditions

of recall for connected, meaningful material but not for single words are related to factors which facilitate recall for anxiety-producing experiences but not for non-anxiety-producing experiences.

3. Nonsense material shows neither hypnotic nor waking hypermnesia. This conclusion was reached in two experiments involving quite different procedures. This result supports those of Huse, Mitchell, and Young with nonsense material.

Thus, we may conclude on the basis of these experiments that the memory process under hypnosis is demonstrably different for nonsense material than for emotional or meaningful material.

(Manuscript received April 6, 1944)

References

1. Bartlett, F. C. *Remembering.* Cambridge, England: Cambridge University Press. 1932.
2. Britt, S. H. Retroactive inhibition: a review of the literature. *Psychol. Bull.*, 1935, **32**, 381–440.
3. Davis, L. W. & Husband, R. W. A study of hypnotic susceptibility in relation to personality traits. *J. abn. soc. Psychol.*, 1931, **26**, 175–182.
4. Flanagan, D. Influence of emotional inhibitions on learning and recall. *Masters Essay.* Chicago: University of Chicago Library. 1930.
5. Hull, C. L. *Hypnosis and suggestibility.* New York: Appleton-Century. 1933.
6. Huse, B. Does the hypnotic trance favor the recall of faint memories? *J. exp. Psychol.*, 1930, **13**, 519–529.
7. McGeogh, J., & McKinney, F. Retroactive inhibition in the learning of poetry. *Amer. J. Psychol.*, 1934, **46**, 19–33.
8. Mitchell, M. Retroactive inhibition and hypnosis. *J. gen. Psychol.*, 1932, **7**, 343–358.
9. Newman, E. Forgetting of meaningful material during sleep and waking. *Amer. J. Psychol.*, 1939, **52**, 65–71.
10. Prince, M. *The unconscious.* New York: Macmillan. 1914.
11. Sharp, A. A. Influence of certain emotional inhibitions on learning and recall. *Masters Essay.* Chicago: University of Chicago Library.
12. Stalnaker, J., & Riddle, E. The effect of hypnosis on long delayed recall. *J. gen. Psychol.*, 1932, **6**, 429–440.
13. Welborn, E., & English, H. L. Logical learning and retention; a general review of experiments with meaningful verbal materials. *Psychol. Bull.*, 1937, **34**, 1–21.
14. White, R. A preface to the theory of hypnotism. *J. abn. soc. Psychol.*, 1941, **36**, 477–505.
15. White, R., Fox, G., & Harris, W. Hypnotic hypermnesia for recently learned material. *J. abn. soc. Psychol.*, 1940, **35**, 88–104.
16. Young, P. C. An experimental study of mental and physical functions in the normal and hypnotic states. *Amer. J. Psychol.*, 1925, **36**, 214–232.
17. Young, P. C. An experimental study of mental and physical functions in the normal and hypnotic states: additional results. *Amer. J. Psychol.*, 1926, **37**, 345–356.

AN EXPERIMENTAL INVESTIGATION OF THE GRADIENT OF REINFORCEMENT IN MAZE LEARNING[1]

BY MERRELL E. THOMPSON

State University of Iowa

I. Introduction and Statement of the Problem

The notion that delay in reinforcement would result in slower learning was first formulated by Thorndike in 1913 as an aspect of his 'law of effect' (18). The problems growing out of Thorndike's original hypothesis have instigated considerable experimental work. Lines of research primarily concerned with some of the implications of this hypothesis are the studies on delay of reward, time discrimination, and distance discrimination. Outstanding among the early investigations were the studies of Watson (20), Kuo (11), Sams and Tolman (16), DeCamp (3), Gengerelli (5), Dennis (4), Clements (2), Hamilton (7), Warden and Haas (19), Roberts (15), Yoshioka (22), Wolfe (21), Skinner (17), and Anderson (1). Other aspects of the problem have been dealt with more recently by Grice (6) and Perin (13, 14).

The theoretical implications of the time interval separating the reaction being conditioned from the reinforcing state of affairs were not given systematic treatment until 1932 when Hull's article on the goal gradient hypothesis and maze learning appeared (9). Hull not only assumed that acts become more strongly conditioned to their stimuli the more closely they are followed by reinforcement, but also that the gradient of reinforcement has a definite mathematical form. Thus, Hull showed that the experimental phenomena of backward order of learning of blind alleys required a negatively accelerated gradient, the increment of reinforcement decreasing with distance (spatial or temporal) from the goal. His treatment also showed how various other maze phenomena followed from the gradient of reinforcement which he postulated.

One of these, that the learning to take the shorter of two alternative maze paths leading to the goal will be slower the greater the absolute lengths of the two paths, even though the difference in short and long paths remains constant, has recently been corroborated by Grice (6). Grice ran five groups of rats in a maze in which the

[1] The present paper constitutes a portion of a dissertation presented to the Faculty of the Graduate College of the State University of Iowa in partial fulfillment of the requirement for the degree of Doctor of Philosophy. The writer is deeply indebted to Professor Kenneth W. Spence who directed the investigation.

absolute lengths of two alternative paths were varied for each group by adding sections to a final path common to both of them. As the theory demanded, each addition to the paths resulted in slower learning.

On the basis of an experiment carried out by Yoshioka (**22**), which tended to show that learning to discriminate between the short and long paths in the alternate pathway maze was independent of the absolute lengths of the paths and a function only of the ratio of the alternative path lengths, Hull was led to make the further specification that the gradient of reinforcement was logarithmic in form. Yoshioka's experiment consisted in running subjects at two different absolute lengths of maze paths for several different long-short path ratios. His experimental results indicated that speed of learning at a given ratio was constant for the two different absolute lengths, and that learning became more difficult the nearer the ratio of the lengths of the two paths approached unity. The results were interpreted by Yoshioka as evidence that the discrimination of maze path lengths by rats followed Weber's law.

In his more recent book (**10**), however, Hull has suggested that the gradient of reinforcement is exponential rather than logarithmic in form. Both logical and empirical reasons were given for this change. Thus, the assumption of a logarithmic function involved the absurd implication that the increment of reinforcement is infinite at zero delay and that at very long delays the increment actually shifts to negative values. Furthermore, the results of a study on time discrimination reported by Anderson (**1**), and the experiment of Grice referred to above, were found to be more in line with implications of the exponential function. The relation of these results and the earlier findings of Yoshoika to Hull's more recent theoretical formulation will be discussed later in connection with the data of the present experiment.

The present study was aimed at investigating further the nature of the delay of reinforcement gradient in maze learning. Whereas Yoshioka employed only two different absolute lengths of pathways for each long-short path ratio, the present study attempted to compare the rate of learning in this alternative path type of situation for several different absolute lengths of maze path. It differs from Grice's study in that the latter altered both the ratio and absolute lengths of the alternative paths, and is similar to Anderson's study except that the delay of reinforcement following the critical response involved different lengths of paths [2] rather than different periods of delay on constant length paths to the goal.

[2] On the average, of course, the longer the path to the goal following the critical response the greater was the period of delay of the reinforcement.

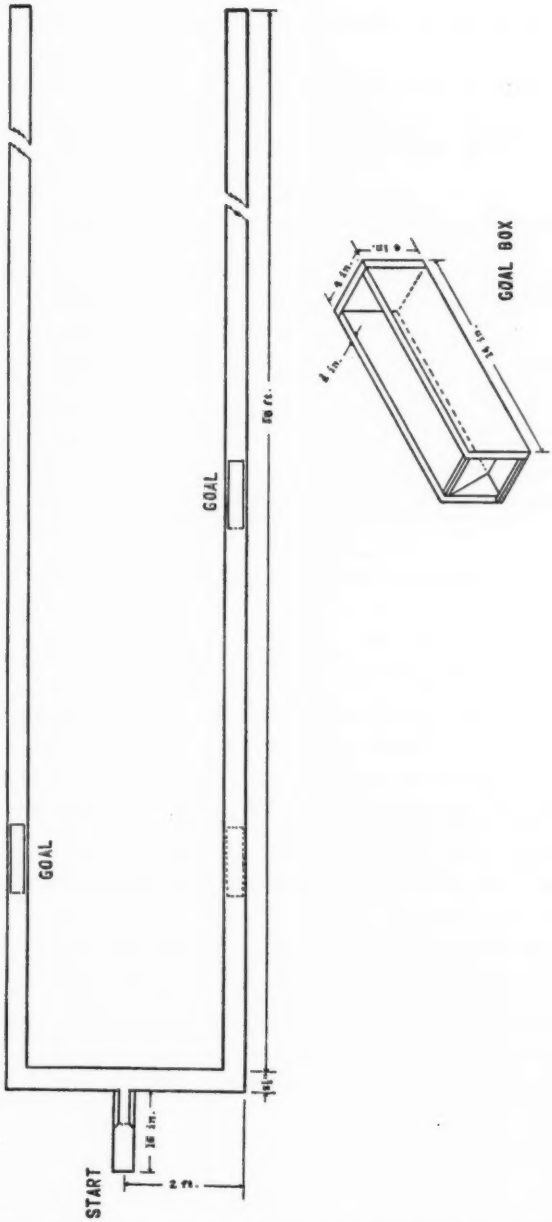

FIG. 1. Ground plan of the experimental maze. The location of the goal boxes could be changed in a few seconds to make either path the long or short one by sliding them up or down the alleys as shown by the dotted lines. An enlarged illustration of a goal box is shown below the maze.

More specifically, the present experiment was designed to ascertain whether the difficulty of learning to discriminate between pathways of different length would be constant for different absolute lengths (assuming their ratios to be constant) as demanded by the assumption of a logarithmic gradient of reinforcement, or whether this learning would vary with the absolute lengths of the pathways.

II. Experimental Procedure

A. *Apparatus*

The maze employed in the present experiment consisted of a single choice point as shown in the floor plan in Fig. 1. The lengths of the paths beyond the point of choice could be varied from two to 60 feet by means of sliding food boxes which fitted inside the maze paths. A hinged single-valve door, fastened on the front of the food boxes, prevented retracing from the goal. The location of the food boxes shown in the drawing illustrates how the maze was set up for a given subject on Group I of the experiment (ratio 2:1). The location of the food boxes could be changed in a few seconds to make either path the long or short one by sliding them up or down the alleys as shown by the dotted lines.

Constructed of white pine and painted a flat black, the maze alleys were 4 in. wide by 3½ in. high, and covered with hardware cloth. The short alley leading up to the choice point from the starting box was only 2½ in. wide in order to minimize the effect of following one wall up to the point of choice. The food boxes were 14 in. long and fitted snugly inside the 4-in. alleys. The experimental room was lighted in such a manner as to provide uniform illumination over both paths.

B. *Subjects*

The *S*s consisted of 167 female albino rats from the colony maintained by the Psychology Department of the State University of Iowa. At the beginning of the experiment they were between 90 and 100 days old.

C. *Preliminary Training*

After being placed on a regular feeding schedule for a week, all animals were placed in one of the food boxes and allowed to eat. They were then trained to run a straight alley six feet long within five seconds in four out of five successive trials. The food boxes in this straight alley contained the same type of hinged single-valve door as was employed in the experimental series in order to give training in opening such a door. This preliminary training reduced greatly the amount of exploratory behavior during the early trials in the experimental maze.

D. *Learning Series*

The learning series in the experimental maze was begun the day following completion of the preliminary training. On the first run of all animals both paths were long and the path chosen by an animal then became the 'long' path for that animal for the remainder of the experiment. Each *S* was given four runs daily. The first two runs each day were free runs with both paths open. On the next two runs of the day the animal was forced to take either one of the paths so that in the four daily runs two runs were made to each of the long and short paths. In order to avoid the development of a simple alternating response, the forced runs were arranged in such a manner as to produce one of the following patterns of daily choices: LLRR, RRLL, LRRL, RLLR. Thus, when the first two free runs were made to the left (L) the forced runs were both made to the right (R), etc. Forcing a response to one side or the other was accomplished by dropping a door in one of the pathways two in. beyond the choice point.

The learning series continued until each animal satisfied the criterion of choosing the short path on the first two daily runs for three consecutive days, or in other words, six consecutive free runs to the short path. However, all *S*s were discontinued after 20 days if they had not satisfied this criterion and the number of their trials to learn was tabulated as 40, i.e., 40 pairs of trials on each path. In order to avoid alternation of response because of 'refractory phase' (8), animals

were rotated in their runs in such a manner that there was a minimum of 15 min. between trials. The order of running for each day was determined by a table of random numbers.

A small pellet of the rat's regular diet (Purina Dog Chow) weighing an average of .15 gm. was placed in each food box as the incentive. The animals were fed their daily ration, consisting of eight gm. of Purina Dog Chow, immediately following the daily experimental period.

E. *Experimental Conditions*

A preliminary experiment was run in order to determine the degree of difficulty involved in learning a maze problem when the ratio between long and short path was held constant at 1.20:1. The conditions of the preliminary experiment are shown schematically in following Table I.

TABLE I

CONDITIONS OF PRELIMINARY EXPERIMENT I

Group	N	Short Path	Long Path
I	4	18 feet	21.6 feet
II	5	24 feet	28.8 feet
III	9	32 feet	38.4 feet

This preliminary investigation suggested that a ratio of 1.20:1 was too fine for ready learning in this maze situation. As a result it was decided to use a coarser ratio of 2:1 in the main experiment. The details of the experiment involving a 2:1 ratio are shown schematically in Table II.

TABLE II

CONDITIONS OF EXPERIMENT II

Group	N	Short Path	Long Path
I	20	6 feet	12 feet
II	20	12 feet	24 feet
III	20	15 feet	30 feet
IV	17	18 feet	36 feet
V	13	29 feet	58 feet

Due to circumstances beyond the control of the experimenter, it was necessary to discontinue this experiment after the number of *Ss* indicated had learned. A final experiment involving a ratio of 1.3:1 was then run in which the following conditions held.

TABLE III

CONDITIONS OF EXPERIMENT III

Group	N	Short Path	Long Path
I	10	6 feet	7.8 feet
II	10	11 feet	14.3 feet
III	14	15 feet	19.5 feet
IV	9	20 feet	26.0 feet
V	9	32 feet	41.6 feet
VI	7	45 feet	58.5 feet

III. EXPERIMENTAL RESULTS

The results of the present investigation are shown in Tables IV, V and VI, representing ratios 1.20:1, 2:1, and 1.30:1, respectively.

TABLE IV

THE PERCENT OF ANIMALS IN EACH GROUP IN EXPERIMENT I (RATIO 1.20:1) THAT REACHED A LEARNING CRITERION OF SIX SUCCESSIVE FREE RUNS TO THE SHORT PATH, THE MEAN NUMBER OF ERRORS MADE IN 20 DAYS (40 FREE RUNS), AND THE MEDIAN NUMBER OF PAIRS OF TRIALS ON BOTH PATHS

Group	N	Percent of Rats Reaching Criterion	Mean Number Errors	Median Pair of Trials
I	4	25.0	23.5	40
II	5	80.0	13.6	22
III	9	55.5	15.3	34

TABLE V

RATIO 2:1

Results with the 2:1 ratio, each column having the same significance as the corresponding column in Table IV.

Group	N	Percent of Rats Reaching Criterion	Mean Number Errors	Median Pair of Trials
I	20	100	4.45	8
II	20	100	6.85	13
III	20	100	6.75	12
IV	17	100	4.64	8
V	13	100	6.61	12

TABLE VI

RATIO 1.30:1

Results with the 1.30:1 ratio, each column having the same significance as the corresponding column in Table IV.

Group	N	Percent of Rats Reaching Criterion	Mean Number Errors	Median Pair of Trials
I	10	70.0	13.00	25
II	10	80.0	10.60	19
III	14	92.8	6.64	12
IV	9	88.8	9.22	18
V	9	22.2	18.44	40
VI	7	71.4	13.14	30

and are illustrated graphically in Fig. 2. The relative difficulty of learning the long-short path discrimination as shown by both mean number of errors and median trials varies with the absolute length of the paths as well as the ratio.

The *F*-test lends itself admirably to these data, as it tests the assumption that there is no difference in means of randomized samples drawn from the same population. If learning to discriminate between different length paths is a function only of the relative distance (logarithmic assumption), then we would expect the group means, where the absolute lengths of paths are varied while the ratio

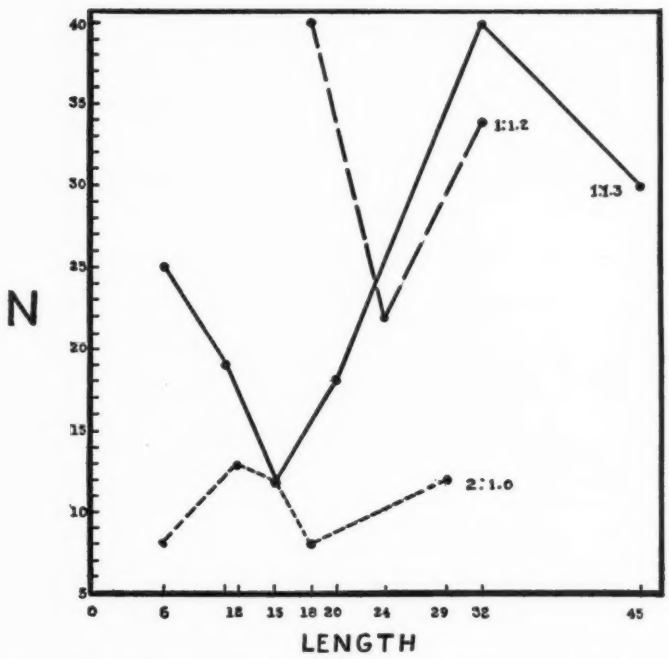

FIG. 2. Graph showing the number of trials on each of the two paths required for one hundred percent selection of the short path plotted against the length in feet of the short path. Each ratio of the present experiment is represented by a different line.

of long to short path is held constant, to differ to no greater extent than could be attributed to chance fluctuations. By applying this simple analysis of variance test of significance (**12**) to the 1.3:1 ratio, we find that we can reject at beyond the one-percent level of confidence the null hypothesis, which is in this case synonymous with the logarithmic assumption in that they both assume no difference in the group means; the analysis of variance for the errors gives an F for the 1.3:1 ratio of 3.94 with 5 and 53 degrees of freedom. The same analysis for N (the number of pairs of trials on both paths) yields an F for the 1.3:1 ratio of 4.74 with 5 and 53 degrees of freedom.

Still another picture of the relative difficulty of discrimination is presented by Fig. 3 which illustrates graphically the number of animals run in each group on the 1.3:1 ratio, the number reaching the criterion, and the number that extinguished. A further examination of Table V shows that the proportion of animals reaching the

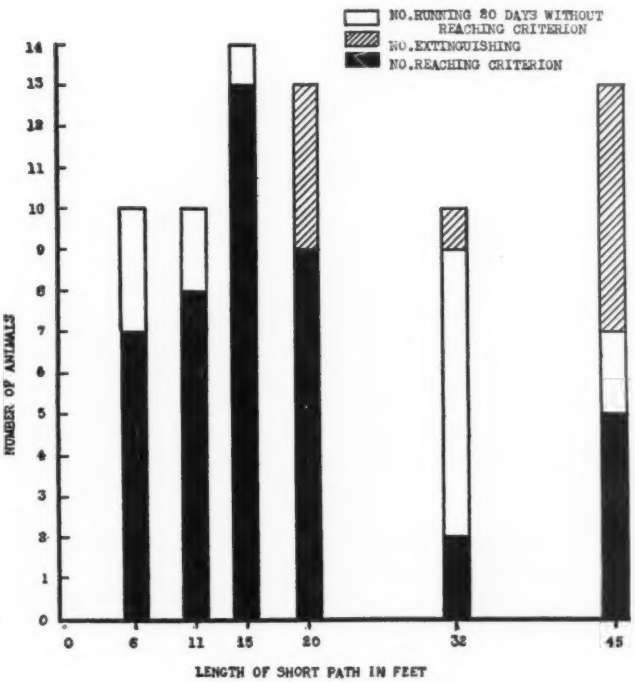

FIG. 3. Graphical representation of the number of animals run in each group on the 1.30:1 ratio, the number reaching the criterion and the number that extinguished, i.e., refused to run the maze for two consecutive days.

criterion on the 2:1 ratio is identical for the five groups, that is, 100 percent; this is to be expected on the coarser ratio as learning would be easier.

IV. DISCUSSION

A. *Relation of the Data to the Form of the Delay of Reinforcement Gradient.*

In the light of the results of Yoshioka's investigation (**22**), it will be recalled that Hull (**9**) postulated at first that the rate of learning varied as a function of the logarithm of the amount of time or space separating the response and the reinforcing state of affairs. The logarithmic function applied to the delay of reinforcement situation requires that all pairs of delays of equal ratio, with equal training, yield equal percents of preference for the act associated with the shorter delay or path (Weber's Law). This implies that the ease

of learning the selection of the shorter of two paths is a function only of the relative distance and not of their absolute lengths. The implications of the exponential hypothesis are quite different. According to it, all pairs of acts whose delays of reinforcement involve the same ratio will not be equally discriminable; moreover, as Hull and Grice have shown, discriminability or ease of learning such discriminations will be optimum at intermediate delays and will

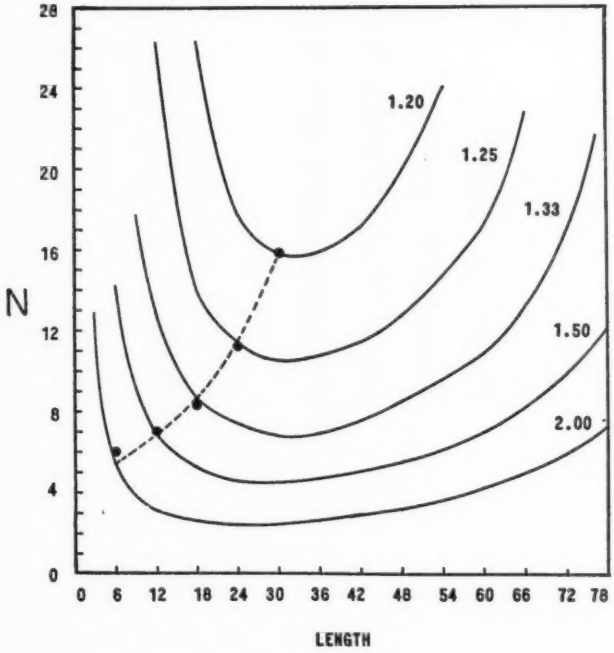

FIG. 4. Graph showing the relation of the data to the revised hypothesis. The family of curves in the figure shows the number of trials on each of the two paths that would be required for one hundred percent selection of the short path plotted against the length in feet of the short path. Each curve represents one of the ratios of Grice's experiment. These curves are computed from the constants found for Grice's data. The points of intersection of these curves with the dotted curve cutting across are the theoretical numbers of trials required for learning in this experiment. The black circles indicate the empirical data. (From Grice, 6.)

decrease with greater and lesser absolute delays of reinforcement. Still another implication of this hypothesis is that this point of optimum discriminability will shift to longer absolute delay values as the ratios of the delays decrease.

A graphic representation of these various implications is shown in Fig. 4, reproduced from Grice's study (6). This graph shows the

theoretical difficulty (number of pairs of trials) required to learn to take the shorter of two paths, the length of which is shown along the abscissa. Each curve represents a different ratio of the lengths of the long to short path. As is clearly shown, there is for each curve an optimum region of learning which shifts to the right, i.e., toward longer delays, as the ratio of the paths decreases. These curves were calculated from a rational equation, the

$$N = I/i \log \left(\frac{(10^{-kL} - 10^{-kHL})}{10^{-kL} - 10^{-kHL} - A} \right)$$

derivation of which was based on the assumption that the delay of reinforcement gradient is an exponential function.

Grice's own experimental data did not provide a test of the above implications of the exponential gradient, as his experiment involved simultaneous variation of both the absolute lengths of the paths and their ratios. The extent to which his data do support the exponential function is nevertheless revealed by the closeness with which the rational curve, shown by the dotted line fits the experimental values (filled circles).

Yoshioka's results do not provide critical evidence so far as the exponential and logarithmic gradients are concerned. His finding, that the ease of setting up the short-path preference was approximately the same for the two mazes of different absolute lengths so long as the ratio of the long to short path was the same, is quite possible according to the exponential hypothesis as well as the logarithmic one. Thus, for example, if we examine Fig. 4, we see that the theoretical number of pairs of trials for a maze with a long-short ratio of 1.33:1 would be just under eight both for a maze in which the short path length was 21 feet and one in which the short path was 42 feet long.

Hull (10) has recently shown that Anderson's experiment (1) in which rats were required to make a choice between two detention chambers leading to a goal provides data which strikingly confirm some of the implications of the exponential gradient. Thus, the results of Table VII, which show the percent of choices of acts

TABLE VII

THE PERCENT OF CHOICES OF ACTS ASSOCIATED WITH THE SHORTER OF TWO DELAYS AS REPORTED BY ANDERSON

Ratio	Length of Short Delay			
Long:Short	10 sec.	30 sec.	60 sec.	120 sec.
2:1	74%	76%	85%	70%
3:1	80%	89%	87%	82%

associated with the shorter of two delays, demonstrate that ease of discrimination varies systematically with the absolute length of delay. The results also substantiate the implication of the hypothesis that this optimum discriminability will shift to longer absolute delay values with smaller ratios of delay. Anderson's results are remarkably consistent in view of the small number of *S*s employed. His groups were composed of as few as four animals and in no case more than eight.

The present experiment parallels that of Anderson, except that the discrimination is between different length paths to a goal rather than different lengths of detention periods. The present experiment also attempts to equate the number of reinforcements of each of the alternative paths as the theoretical picture presented by Grice's graph demands. The results in terms of the median pair of trials on both paths required to reach the criterion are shown in Fig. 2. It will be observed that the graph has certain features in common with the theoretical picture. In agreement with theoretical expectation is the tendency of the two curves for the smaller ratios to begin at high values, fall to a minimum and then rise again with increase in the absolute length of the short path. Also in accord with theory is the much flatter (although somewhat irregular) curve for the large ratio (2:1) and the fact that the low point in the 1.2:1 curve is farther to the right than that for the 1.3:1.

Quite in disagreement with the theory, however, is the fall of the 1.3:1 curve at the longest length of short path. This result is entirely inconsistent with the exponential gradient of reinforcement. Also difficult to account for on other than a sampling basis is the fact that the curve for the 1.2:1 ratio falls below the 1.3:1 ratio curve at one point and the 1.3:1 and 2:1 curves fall at the same point when the short path of each is 15 feet.

B. *Interpretation of the Data in Terms of a Theory of 'Work' Inhibition.*

In his original formulation of the goal gradient hypothesis Hull (9) defined the delay of reinforcement in terms of space or time. In his more recent formulation the delay variable is specified as being a temporal one—the time separating the reaction from the reinforcing state of affairs. In the type of delayed reward situation employed by Anderson the experimental variable was measured in terms of time. In the Yoshioka, Grice, and present experimental situations, however, the experimental variable was distance (length of maze path). While there is presumably a fairly close correlation between the length of a delay path and the average time of delay,[3] the spatial

[3] For the 1.3:1 ratio the median time on the short and long paths, respectively, are as follows: Group I, 6.6 and 10.4; Group II, 8.0 and 10.0; Group III, 14.8 and 14.4; Group IV, 13.9 and 23.4; Group V, 22.4 and 25.1; and Group VI, 43.7 and 50.58.

maze situation does introduce a definitely new factor—a differential amount of activity or 'work' between the to be learned response and reinforcing situation.

Grice concluded from a study of the times of his *S*s that rate of learning in the maze situation was probably more a function of this distance (activity) factor than of the temporal one. The results of Anderson's study, on the other hand, would seem definitely to establish the effectiveness of the time variable although the possibility exists that his *S*s 'worked' more, i.e., were more active during long delay than in short delay periods. Until an experiment is arranged in which these two factors, 'work' or activity and time are independently varied, it is not possible to conclude definitely which one of them is the effective variable or whether both of them are effective.

In his recent book Hull has taken the position that both variables are probably operative in the long-short path maze situation. He assumes that each reaction of an organism builds up a condition or state within it "which acts as a primary negative motivation in that it has an innate capacity to produce a cessation of the activity which produced the state." This state is called reactive inhibition or inhibitory potential (I_R). Moreover, Hull assumes that this inhibitory potential will become conditioned to stimuli which are closely associated with its accumulation. This latter leads to conditioned inhibition (${}_sI_R$).

Applied to the present type of situation this theory would imply that because the I_R generated by traversing the long path would be greater than that generated by traversing the short path, the conditioned inhibition (${}_sI_R$) against the long-path response would be greater than that against the short-path response. As this ${}_sI_R$ enters into the determination of the response strength (effective excitatory potential (${}_s\bar{E}_R = {}_sE_R - {}_sI_R$), that for the short-path response will be the greater, and the animal will come to take this path even though the time of delay were equated in the two paths.

One possibility is that the drop in the 1.3:1 curve for the longest maze was brought about in some way by this 'work' inhibition factor. The implication of the particular mathematical assumption made by Hull as to the development of inhibition is that with the holding of time of delay constant for the alternative responses, the rate of learning to choose the shorter path would be a hyperbolic function of the length of the shorter path. The effects of the two variables interacting together, however, are more difficult to estimate.

V. Summary

In the present investigation, designed to determine whether long-short path discriminability remains constant with different absolute

path lengths, assuming a constant long-short path ratio, as demanded by the assumption of a logarithmic gradient of reinforcement, or whether this learning is a function of both the absolute path lengths and ratio, 167 rats were run in a long-short path maze situation with three ratios.

1. Both mean number of errors and median trials showed that the relative difficulty of learning the long-short path discrimination was dependent upon the absolute lengths of the paths as well as the ratios. The statistical significance of these variations was beyond the one-percent level as determined by the analysis of variance test.

2. The results agree with the exponential assumption in so far as (1) the curves for the smaller ratios show a maximum discriminability at a central point of absolute lengths, which diminishes with both increase and decrease in path length, and (2) in general the point of maximum ease of discrimination shifted toward the longer path length on the finer ratios.

3. The sudden increase in discriminability on the longest length of short path indicated that a factor other than delay, possibly 'work' inhibition, may be operative in this type of maze situation. Since the two factors are not varied independently in this situation it is impossible to conclude definitely the extent of the effectiveness of each.

(Manuscript received March 21, 1944)

Bibliography

1. Anderson, A. C. Time discrimination in the white rat. *J. comp. Psychol.*, 1932, **13**, 27–55.
2. Clements, F. E. The effect of time on distance discrimination in the albino rat. *J. comp. Psychol.*, 1928, **8**, 317–324.
3. DeCamp, J. E. Relative distance as a factor in the white rat's selection of a path. *Psychobiol.*, 1920, **2**, 245–253.
4. Dennis, W. A study of learning in the white rat. *J. genet. Psychol.*, 1930, **37**, 294–308.
5. Gengerelli, J. A. The principle of maxima and minima in animal learning. *J. comp. Psychol.*, 1930, **11**, 193–236.
6. Grice, G. R. An experimental study of the gradient of reinforcement in maze learning. *J. exp. Psychol.*, 1942, **30**, 475–489.
7. Hamilton, E. L. The effect of delayed incentive on the hunger drive in the white rat. *Genet. Psychol. Monogr.*, 1929, **5**, 131–207.
8. Heather, G. L. The avoidance of repetition of a maze reaction in the rat as a function of the time interval between trials. *J. Psychol.*, 1940, **10**, 359–380.
9. Hull, C. L. The goal gradient hypothesis and maze learning. *Psychol. Rev.*, 1932, **39**, 25–44.
10. Hull, C. L. *Principles of behavior.* N. Y., 1943, D. Appleton Century.
11. Kuo, Z. Y. The nature of unsuccessful acts and their order of elimination. *J. comp. Psychol.*, 1922, **2**, 1–27.
12. Lindquist, E. F. *Statistical analysis in educational research.* N. Y., 1940, Houghton Mifflin.
13. Perin, C. T. A quantitative investigation of the delay-of-reinforcement gradient. *J. exp. Psychol.*, 1943, **32**, 37–51.
14. Perin, C. T. The effect of delayed reinforcement upon the differentiation of bar responses in white rats. *J. exp. Psychol.*, 1943, **32**, 95–109.
15. Roberts, W. H. The effect of delayed feeding on white rats in a problem cage. *J. genet. Psychol.*, 1930, **37**, 35–58.

16. SAMS, C. F., & TOLMAN, E. C. Time discrimination in white rats. *J. comp. Psychol.*, 1925, **5**, 255–264.
17. SKINNER, B. F. *The behavior of organisms; an experimental analysis.* N. Y., 1938, D. Appleton Century.
18. THORNDIKE, E. L. *Educational psychology*, Vol. I, *The original nature of man.* N. Y., Teachers College, Columbia Univ., 1913.
19. WARDEN, C. J., & HAAS, E. L. The effect of short intervals of delay in feeding upon speed of maze learning. *J. comp. Psychol.*, 1927, **7**, 107–116.
20. WATSON, J. B. The effect of delayed feeding upon learning. *Psychobiol.*, 1917, **1**, 51–60.
21. WOLFE, J. B. The effect of delayed reward upon learning in the white rat. *J. comp. Psychol.*, 1934, **17**, 1–21.
22. YOSHIOKA, J. G. Weber's law in the discrimination of maze distance by the white rat. *Univ. Calif. Publ. Psychol.*, 1929, **4**, No. 10, 155–184.

THE RETENTION OF VERBAL AND OF MOTOR SKILLS

BY HAROLD J. LEAVITT* AND HAROLD SCHLOSBERG

Brown University

There is a wide-spread popular belief that motor habits are retained better than are verbal materials. A large amount of anecdotal evidence may be adduced to support this belief, but the experimental evidence is equivocal. The problem is of considerable importance to anyone who wishes a unified theory of learning.

Much of the experimental evidence comes from comparisons between retention of nonsense syllables and mazes. Thus, Tsai (**18**), after comparing his own stylus maze results with those obtained by Radossawljewitch on nonsense syllables, concluded that "Human subjects retain the maze habit more readily than they do ideational or verbal materials" (p. 27). McGeoch and Melton (**11**), on the other hand, found no reliable differences, except in terms of trials, in which nonsense syllables actually excelled mazes in retention value. Further experiments with similar materials (**9, 19, 20**) brought out additional details, such as the effect of overlearning, but did not settle the main question.

Unfortunately, the maze is a poor representative of motor habits. Husband (**7**) showed that a purely motor method is a poor way of learning a maze. Waters and Poole (**20**) found that the majority of their subjects had learned their maze by a verbal method. Thus, the investigators named above were actually comparing two verbal tasks, rather than a verbal and a motor one. The only study which used anything approaching a motor task was that of Freeman and Abernethy (**3**). They compared retention of typewriting (motor) with translation of typed material into symbols (verbal). After eight weeks the typing task was better retained than was the verbal one. Unfortunately, their results were complicated by a preliminary relearning period at two weeks. This was criticized by McGeoch (**9**), but in a second experiment Freeman and Abernethy (**4**) found that omitting the preliminary retention test increased the difference in favor of the motor skill, typing.

Examination of these experiments indicated three general principles that must be followed if one is to answer the question of the rela-

* A more complete presentation of this experiment will be found in the junior author's M.Sc. dissertation on file in the John Hay Library, Brown University.

tive retention of verbal and motor habits. We will list these principles, and indicate how they were applied in our experiment.

1. The motor task must be as near the end of the verbal-motor continuum (**10**) as possible. We used the pursuit rotor. This task seems to have very little verbal component. As a matter of fact, Renshaw and Postle (**12**) showed that verbal instructions actually hampered performance on a similar task.

2. Both types of material should have equal amounts of practice, and should be learned to about the same degree. We controlled the length of the original learning period, keeping it constant for all subjects for each task. The experimenters mentioned above had continued training until the subjects reached a criterion (usually mastery). The length of the nonsense syllable list was adjusted by preliminary experimentation so that subjects made comparable scores (percent of maximum) on each task. Thus, it is reasonable to suppose that the two tasks were learned to roughly equivalent stages in the original practice period.

3. The units in which retention is measured must be equal for the two tasks. We adopted as our basic method the relearning method. The retention score was the time required to regain the level that had been reached on the last trial of the original learning period, expressed as percent savings.

As we will indicate later, our results were somewhat complicated by marked reminiscence in the pursuit rotor scores. But in a very real sense this was not a complication, for reminiscence is part of the process of retention. As a matter of fact much of the superiority of motor over verbal materials appears in this early up-swing of the curve of retention.

Apparatus and Method

In the present study, the materials compared were (a) nonsense syllables, presented by means of a standard memory drum of the type suggested by Schlosberg (**14**), and (b) a modified Koerth Pursuit Rotor (**8, 15**).

The 15 nonsense syllables finally decided upon were selected from the list prepared by Hull (6). As far as possible the syllables with the lowest association values were chosen. In order of presentation, the syllables were: BEJ, TAH, FEP, POB, YUT, VAB, KEX, ZOY, MIV, HUJ, FAP, ZUK, MEP, NAF, YEV. The syllables were typed in capitals on white paper, and were presented, one at a time, for two sec. each. The memory drum clicked audibly every time a new syllable swung into place.

The pursuit rotor was constructed from an adjustable phonograph motor set for one revolution per sec. The turntable was a disc of Prestwood, 15 in. in diameter. It carried a silver target, the size of a dime, set flush with its surface. The contact stylus was made from a $7\frac{1}{2}$ in. length of 30 gauge brass rod. A 90 degree bend was made $1\frac{3}{4}$ in. from the contact end. The end itself was tipped with silver. The other end of the rod was attached, through a hinged joint, to a wooden handle, in such a fashion that the contact strip could be guided laterally, but could not be forced down against the target. Contact between the silver tip of the stylus and the target closed the circuit through a transformer and a Stoelting electric impulse counter. This permitted a cumulative reading (in .01 sec.) of the duration of all contacts during the 30-sec. trial. The buzz of

the counter acted as a signal to the *S* that he was on the target; it probably had some 'reward' value.

In all, 48 *S*s were used in the final experiments. They were all college students, of whom half were men and half were women, ranging in age from 17 to 25. Further subdivision was made so that half of the *S*s worked first on the nonsense syllables and then on the pursuit rotor, while the other half worked first on the pursuit rotor.

Since the 15 nonsense syllables were presented for two sec. each, one trial lasted 30 sec. The maximum possible raw score was 15 (number of syllables correctly anticipated). On the pursuit rotor, revolving once per sec., each trial was again limited to 30 sec. Since it was theoretically possible to keep stylus and target in contact for all 30 sec., the maximum score was 30.00. Following each trial, on each material, the *S* was given a 30-sec. rest period during which he worked on digit-symbol translations. On his first visit, the *S* received 10 consecutive trials on each material. If he had worked first on nonsense syllables, he was transferred, immediately after his tenth trial, to the other table, where he was given the necessary instructions. He then took his 10 trials on the pursuit rotor. A single session lasted about 25 min., five of which were taken up with instructions and questions.

The directions given the *S*s were, in essence, as follows:

For the nonsense syllables:

"I want you to try to learn some nonsense syllables. A nonsense syllable is a vowel between two consonants. It doesn't mean anything. For example, 'BOK' is a nonsense syllable. The syllables will appear one after another in this opening. You try to learn them. After we've gone through the list once, you try to tell me what syllable is going to appear next. You are to try to anticipate each syllable just before it comes along. After each trial we'll have a short rest. During the rest you try to do this translation test as fast as you can. When we're ready for the next trial I'll say 'ready.'"

For the pursuit rotor:

"This is a pursuit rotor. The turntable will go around at a steady speed and you are to try to hold the tip of this stylus on this target as long as you can. The more time you keep the stylus on the target, the better your score will be. This clock will record the number of seconds you hold the stylus on the right place." (Two or three revolution demonstration by the *E*.)

*S*s were tested one at a time. They were informed of their results after each trial. All timing was done with a stopwatch. All 48 *S*s were given the same original learning session, 10 trials on each material, spaced at 30-sec. intervals. For the retention test, the *S*s were divided into four groups of 12 each, roughly equated in terms of their scores on the nonsense syllables. Group A returned after one day; Group B after seven days; Group C after 28 days; Group D after 70 days.

The *S*s were not told specifically that they were to be tested at a later time, but that they would be notified if they were needed again. In all cases retention was tested within one hour of the time of day at which the original learning had occurred. Three of the 70-day group were retested at 67 days, and two of the 28-day group were retested at 29 days. All others came on the correct day.

The relearning session was similar to the original learning session in every respect except number of trials. Each *S* was given at least two trials beyond that trial in which he reached his former criterion. For example, consider an *S* who had anticipated eight syllables on trial 10 of the original learning. He anticipated five on the first relearning trial, and eight on the second. He was then given two more trials. Actually the additional trials were not used in our treatment of results, but it seemed desirable to have them available if they were needed. He was then tested on the pursuit rotor in a similar fashion. The order of the tasks was the same as that used for each *S* during original learning. *S*s were told their scores on each trial, but were not told how many trials they would be given, or when they had reached the criterion.

Results

1. *Learning*

All 48 *S*s had been given the same original learning task, 10 trials on the nonsense syllables and 10 trials on the pursuit rotor. The number of nonsense syllables anticipated during the 10th trial ranged

from a low of one to a high of 12, out of a possible 15. On the pursuit rotor, the lowest trial score was .09 sec., with the highest score at 20.60 sec., out of a possible 30 sec.

The distribution of scores on each of the 10 learning trials was skewed, with the majority of scores piled up at the lower end of the distribution. Both materials showed this skewness. Both materials also showed a progressive trial-to-trial trend toward less skewed, more normal distributions. It seemed likely, therefore, that the skewness phenomenon was a result of the lower limit set on learning, rather than faulty selection of *S*s or materials. This lower limit made it impossible to differentiate between *S*s in the early trials, for no *S* could receive a score below zero, and few *S*s, at the early stages of learning, were able to obtain high scores. Thus, the frequencies piled up at the zero-score end of the curves. When, however, the middle levels of learning had been reached, there was a wide range of possible scores both above and below the middle point. A bad learner could be singled out by a low score, and a good learner by a very high score. It was at this point that the skewed distributions gave way to fairly normal curves. If learning had continued until the maximum possible scores had been approached, it is likely that the distribution would again have been skewed, this time with the great majority of scores at the high end of the distribution.

On the basis of the above analysis it was decided that these obtained skewed curves were a function of the artificial floor and ceiling

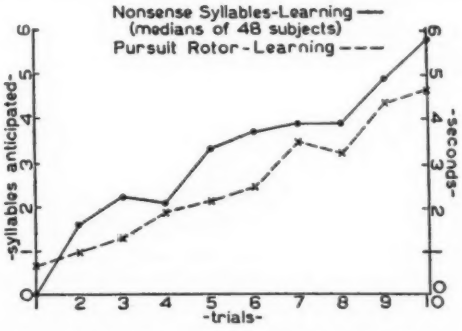

FIG. 1. Original learning curves for the pursuit rotor and nonsense syllables. Refer the nonsense syllable curve to the left hand ordinate; the pursuit rotor curve to the right hand ordinate.

set on the learning process by the units employed. Nevertheless, since the curves were skewed, the measure of central tendency best suited to the data seemed to be the median rather than the mean. The possibility of using logarithmic scores was explored but discarded because of the presence of raw scores of zero. Except where noted,

then, the curves and tables presented below are in terms of the results of the median *Ss*.

The learning curves in terms of median scores are presented in Fig. 1. It may be seen that both curves fluctuate around a straight line, and show no clear evidence of either positive or negative acceleration.

In Table I the median amount learned at the 10th trial for each separate group of subjects is presented. The 12 *Ss* who were to be

TABLE I

MEDIAN LEARNING SCORES AT THE 10TH TRIAL FOR GROUPS ALLOTTED TO DIFFERENT RETENTION PERIODS

	Group				Median for All Groups
	1 day	7 days	28 days	70 days	
Nonsense	6.0	5.5	5.0	4.0	5.8 syllables
Pursuit	3.34	5.86	3.62	8.31	4.67 seconds

tested for retention after one day anticipated a median of six nonsense syllables on their last (10th) learning trial. The same *Ss* had a median score of 3.34 sec. on the pursuit rotor on their last (10th) trial for that material, and so on. It will be noted that the *Ss* had originally been roughly equated in terms of their nonsense syllable results. The differences between groups for the pursuit rotor were unfortunately quite large.

2. *Retention Results*

A. Savings:

In contrast to the original learning scores, the percent savings scores for the groups of *Ss* at various intervals were distributed fairly normally. The mean and other statistics assuming the existence of a normal distribution curve are, therefore, applicable.

Before presenting the retention test results, a word of explanation may be advisable concerning the method adopted for obtaining savings scores. It was found that, for the pursuit rotor, the score on the first relearning trial after the specified interval often surpassed the score on the last (10th) original learning trial. Since, during the entire first relearning trial the 10th trial score was *surpassed*, it seemed wise to use a method that would take account of the *fraction* of the relearning trial required just to reach the established criterion. Any single trial takes a period of time. Assuming for convenience only that the learning during a single trial is uniformly distributed throughout the duration of the trial, the particular fraction of the trial's dura-

tion required to reach a given criterion of learning can be determined. Thus, for example, if an *S*'s pursuit rotor score had been nine sec. on his 10th learning trial, and his score on his first relearning trial had been 10 sec., the *S* had, at some time during this relearning trial, just reached his 10th trial criterion and then had surpassed it. By the method used, this *S* was said to have reached his 10th trial criterion after 9/10ths of his first relearning trial. He had, therefore, saved 1/10th of one trial plus nine other trials, and his savings were recorded as 91 percent. In contrast to the methods usually adopted, no *S* could possibly save more than 100 percent no matter what his first retest score.

The major weakness of this method is that the criterion is the score on the 10th trial, which actually measures what was learned on the ninth trial. A more logical criterion for the nonsense syllables would be a hypothetical 11th trial, obtained by extrapolation of the individual's curves. For the pursuit rotor, in which performance measures learning throughout each trial, we might have used an average of the 10th and extrapolated 11th trial scores. Such extrapolation is probably too uncertain to serve as a basis for individual scores, although we have attempted it with group scores (see below). Since the learning curves were essentially linear, our present treatment

TABLE II

MEAN SAVINGS SCORES AND SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS AT VARIOUS INTERVALS

	Mean	Sigma	Significance Ratio (t)	Level of Confidence
1 day Group				
Nonsense	81.1%	6.10	6.00	0.1 plus
Pursuit	92.7	1.65		
Difference	11.6			
7 day Group				
Nonsense	71.0	17.36	2.37	5.0 plus
Pursuit	85.3	13.70		
Difference	14.3			
28 day Group				
Nonsense	53.1	18.83	4.99	0.1 plus
Pursuit	86.2	10.91		
Difference	33.1			
70 day Group				
Nonsense	51.4	30.50	1.94	20.0 plus
Pursuit	75.2	26.39		
Difference	23.8			

would serve only to increase the apparent amount of saving for both tasks.

The results, computed as we have outlined above, are presented in Table II. In the first vertical column the *mean* savings for each group on each material are presented, followed by the difference between the means. The significance of this difference between the means was determined by Fisher's *t*-ratio and is found in the third column. In the last column the minimum percent level of confidence is given. The word 'plus' indicates that the difference is more significant than indicated, since the confidence levels were taken from Fisher's tables for the *t*-ratio closest to, and lower than, the one actually obtained.

Two of the differences between the means of the materials are clearly significant; the differences after an interval of one day and after an interval of 28 days. The other two are significant enough to warrant consideration. More important is the fact that at all intervals the means are very far apart and give no indications of coming together. If anything, the differences seem to be increasing rather than decreasing as can be seen from the plotted means in Fig. 2. The

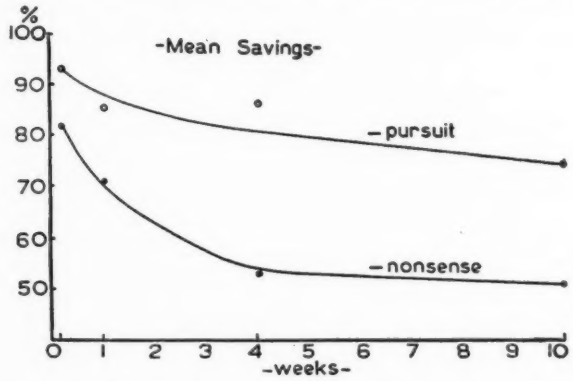

FIG. 2. Percent savings at various intervals. The mean at each interval is obtained by comparing the retention score of each *S* with the score on his last learning trial.

results consistently favor the retention of the pursuit rotor task over the nonsense syllables.

B. A Comparison of the Learning and Relearning Curves of the Two Materials:

If the score of each *S* on each trial is converted into percent of his own last (10th) learning trial score, the score of the median *S* for each trial may be plotted. Thus in Fig. 3, A, B, C, and D, the learning and

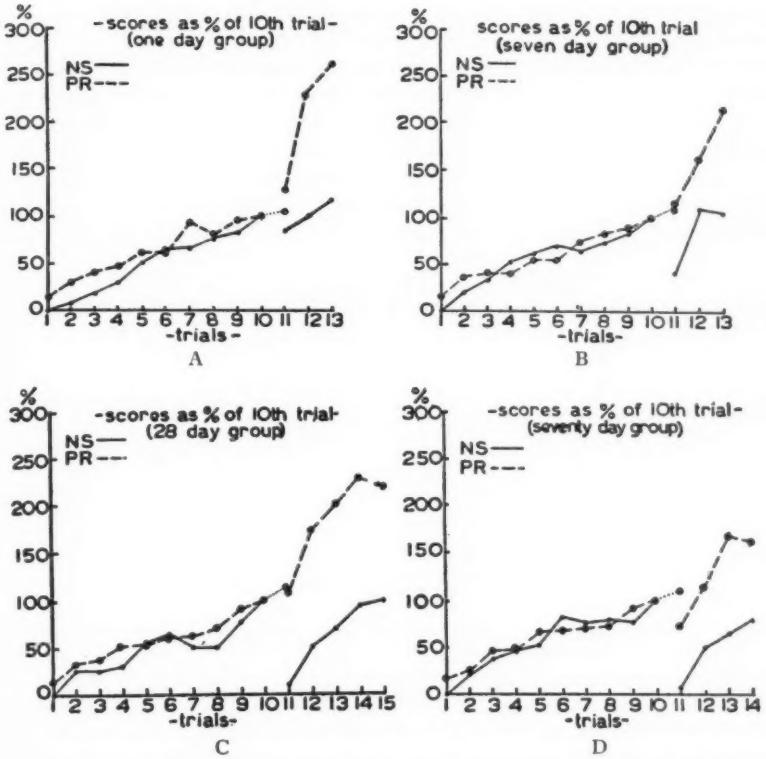

FIG. 3. Original learning curves for each experimental group of 12 *S*s, including trials given after the prescribed interval. The curves are for the median *S* at each trial. The ordinate represents percent of the last (10th) original learning trial.

relearning curves for the nonsense material may be compared with the same curves for the pursuit material for each group of *S*s.

In these curves, the 10th trial represents the last trial of original learning, while the 11th trial represents the first relearning trial after the specified interval of time. The vertical distance between the 10th and 11th trial scores represents forgetting, or its opposite, reminiscence. In all four graphs the pursuit rotor curves begin and remain well above the nonsense syllable curves. In three of the curves for the pursuit rotor, relearning begins at a point above the highest point of the learning curve, while in all four nonsense syllable groups, the relearning curves start at a point well below the maximum point reached in original learning. It may thus be said that reminiscence on the pursuit rotor no longer appears after 28 days. Even if we

extrapolate the curves (shown in dotted lines) to obtain the expected scores on the hypothetical 11th trial that we described above, there is evidence of reminiscence in both the 1- and 7-day groups for the pursuit rotor, but none at any interval for the nonsense syllables.

To show that the characteristics of our curves of retention are not due to our use of the method of savings, we have computed the more usual type of retention curve. The first retest trial score of each *S* was expressed as a percentage of his last learning trial score. Median percentages for each group on each task were then plotted in Fig. 4.

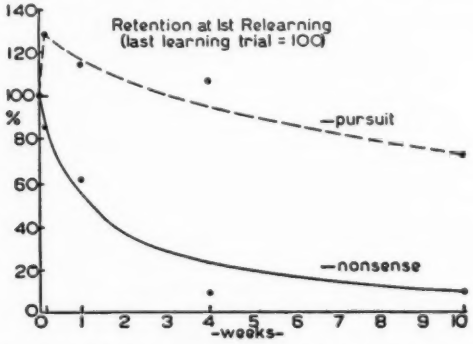

FIG. 4. Amount retained at the first relearning (11th) trial. Again, the last (10th) original learning trial equals 100. The ordinate is in terms of percent of the last learning trial.

The nonsense syllable curve is negatively accelerated in the orthodox fashion. The pursuit rotor curve shows a preliminary rise, indicating that the first retest trial of the 1-day group was 25 percent above the level reached at the end of the original learning. The pursuit rotor curve falls somewhat more slowly than does that for nonsense syllables, and apparently does not fall below the 10th trial level until about a month after original learning.

Essentially the same thing is found if we consider the number of *S*s who performed better on the first retention trial than they did on the last learning trial. Only one *S* showed reminiscence on the nonsense syllables, and he was a member of the 1-day group. But on the pursuit rotor, 11 out of 12 *S*s of this group showed reminiscence. Similarly, 7 showed it at 7 days, 6 at 28 days, and 5 at 70 days.

C. Miscellaneous Results:

It may be of interest to note that, in the conversations following the experimental periods, no *S* reported the use of verbal methods in practicing the pursuit rotor, although one reported that "there must be some trick to it," and that he had been seeking that trick.

As to preference for one material over the other, 12 *Ss* definitely preferred the nonsense syllables, 27 favored the pursuit rotor, and nine were indifferent. There seemed to be no clear relationship between preference for, and success in, learning the two types of material.

Discussion

The original aim of this investigation was to determine whether or not a specific motor skill is better retained than is a specific verbal one. It may be argued that the problem has not been solved because the results obtained are obscured by the occurrence of reminiscence on the pursuit task. Since reminiscence is, after all, simply one phase of retention, that argument would not seem valid. However, it would be of interest to determine whether or not the pursuit task would have been the one better retained, had no reminiscence occurred. In order to answer such a question, the nature of the phenomenon of reminiscence, at least as it occurs here, would have to be considered. An hypothesis as to the nature of reminiscence follows, and is itself followed by an attempt to determine retention differences between the two experimental materials when the effects of reminiscence have presumably been factored out.

Possible Explanation of Reminiscence

From the extensive experimentation and discussion devoted to 'explaining' reminiscence, three factors have emerged. We will consider how each may apply to our results.

1. Perseveration. In its most obvious form, rehearsal of the learned material between learning and retesting, this process might apply to the nonsense syllables, but it is hard to see how *Ss* could practice on a pursuit rotor after they had left the experimental chamber. Yet we found little reminiscence for nonsense syllables, and a large amount of reminiscence for the pursuit rotor. Rather than assume some obscure symbolic process to explain our results on the pursuit rotor, we are inclined to turn to other possible factors.

2. Neglect of the effect of the last learning trial. In the learning of nonsense syllables it is clear that the last trial measures what was learned on the preceding trial. To measure the number of nonsense syllables actually learned in 10 trials it would be necessary to use a zero-interval control group. One could then compare the scores of the various delay groups with that of the control group. The necessity for such treatment is less obvious in the pursuit rotor, since the task is repetitive rather than serial. We have attempted to estimate the scores on the hypothetical 11th trial for the pursuit rotor by

extrapolation. There was still a large amount of reminiscence left even after correction for the amount learned on the last trial.

3. Performance decrement. This theory assumes that the actual amount that has been learned does not show up in the score on a given trial. The score is lowered by such factors as fatigue, tension, interfering habits, and inhibition of reinforcement. It is further assumed that these decremental factors are dissipated rapidly, unmasking the actual amount that has been learned. Thus, the *performance* after an interval may be higher, although there has been some forgetting, because the *S* has lost the factors which had depressed performance during the later trials of the original learning.

This theory seems to offer the most logical explanation of the reminiscence we found on the pursuit rotor. There is abundant evidence for the action of a decremental factor in our results. Travis (**16, 17**) found that the pursuit rotor yields a positively accelerated curve when trials are spaced. But when trials are massed the curve rises slowly and linearly. Doré and Hilgard (**2**) found linear curves for that portion of pursuit learning in which trials were massed, and an accelerated curve when trials were spaced. Webb (**21**) and Renshaw and Schwarzbeck (**13**) also found that spaced practice has an advantage over massed practice, at least in the early stages of learning. Massing of trials apparently permits the accumulation of decremental factors, as Hovland (**5**) demonstrated so clearly. Thus, the curve of *learning* is probably accelerated, but the decremental factors depress the curve of performance, making it more or less linear. It is difficult to compare the actual spacing of trials in our experiment with those reported above, but the linearity of our pursuit rotor curves suggests the presence of decremental factors from massed practice.[1]

If the reminiscence we found on the pursuit rotor is the result of the rapid dissipation of decremental factors, it is a simple matter to factor it out, and to obtain something approaching pure retention curves for both tasks. Presumably most, if not all, of the decremental elements have disappeared overnight, for the one day retention group shows by far the greatest reminiscence. We can, therefore, take the performance of this group as the beginning of the forgetting curve, and compare the performance of all other groups to this level. This method will cut off any forgetting that occurred during the first 24 hours, but it will permit us to compare the later portions of the retention curves for the two types of materials.

In Fig. 5 we have plotted the results of this treatment of the data. The median score on the first retest trial of the 1-day group was considered as 100%, for both materials. Similar scores for the other groups were expressed in percentages of those for the 1-day group.

[1] For a more detailed study of the factors involved, see (**1**).

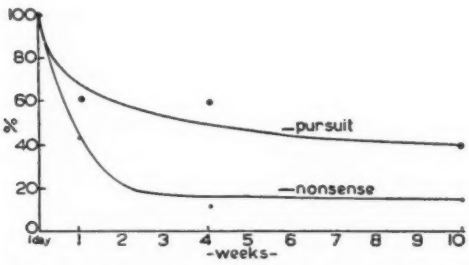

FIG. 5. Retention at longer intervals in relation to retention after one day. The retention of each material by the 1-day group is set at 100. Differences in original learning have been corrected.

Differences in original learning among the groups (due to poor matching) were eliminated by finding the ratio between the 10th trial score for the 1-day group and that for each of the other groups. The percentages were corrected by multiplying by the appropriate ratio. The resulting curves represent the later stages of retention with most, if not all, of the reminiscence parcelled out. It is clear from the curves that the motor task was retained much better than was the verbal one, up to a period of 10 weeks. We would also hazard a guess that the difference would show up over a much longer retention period.

Possible Explanation of the Relatively Better Retention of Motor Learning

Under the conditions of our experiment, a specific motor task is retained better than is a verbal one. We are not justified in generalizing further to include all motor and verbal learning. The relationship might not even hold true for the two tasks we have used, if the conditions, spacing of trials, etc., were changed. We must await further experimentation before we can even be certain of the explanation of the difference we have observed. But it might be well to point out two possible factors, if only to guide future research.

1. Nonsense syllables present a much less integrated task than does the pursuit rotor. Remote associations undoubtedly tie all the syllables together, but the task is essentially one of yoking successive items together in a chain. Any similar analysis of pursuit would be artificial. The disc does make a complete rotation every second, but such rotations are in no sense behavioral units. Instead the task seems to be the integration of visual, auditory, and kinaesthetic cues with a smooth circular motion of the hand. It is possible that pursuit learning is retained better because it is integrated better. One could test this hypothesis by measuring retention on an integrated verbal task, such as learning paragraphs. If the hypothesis is correct, para-

graphs should resemble the pursuit rotor rather than nonsense syllables in terms of relative retention. If this were true, we would conclude that the significant thing is not whether the material is verbal or motor, but whether it is serial or unitary.

2. Retroactive inhibition. We do not believe that all forgetting is the result of the interference exerted by new material on the retained traces of previous learning. But such a retroactive effect is undoubtedly important, and may well be a significant factor in our results. Nonsense syllables should suffer considerably from interference exerted by the constant verbal tasks of ordinary student life. But there would seem to be few ordinary tasks that are related to the pursuit rotor. Even if there were, it is likely that they would yield positive transfer rather than interference. Very few of the tasks of everyday life are opposed to pursuit movements, unless the *S* engages in some sport that involves avoiding small objects. On the other hand, almost any verbal activity might interfere with nonsense syllable lists, for language involves constant changing of connection between syllables. The test for this hypothesis could be made most readily by testing a motor task that is subject to a large amount of retroactive inhibition or negative transfer from daily tasks. If our hypothesis is true, such a task should resemble the nonsense syllable, rather than the pursuit rotor in terms of retention. Unfortunately, a good example of such a motor task is hard to find. At the present moment all we can say is that retroactive interference of daily verbal behavior may well depress the nonsense syllable curve of retention below that of the pursuit rotor.

Summary

1. Each of 48 *S*s was given 10 repetitions of a list of 15 nonsense syllables and 10 30-sec. trials on a pursuit rotor. They were then divided into four groups, and tested for retention after 1, 7, 28, and 70 days, respectively.

2. At all four intervals, the pursuit habit was retained better than was the nonsense syllable list. The differences appeared in percent savings and in raw scores on the first retest trial.

3. Almost no reminiscence was found on the nonsense syllables, but the average score on the pursuit rotor for the 1-day group was much better on the first relearning trial than it had been on the last learning trial. The retention curve for the pursuit rotor crosses the 100 percent point at about 30 days.

4. An explanation of the reminiscence found on the pursuit rotor is presented in terms of the dissipation of decremental factors which had depressed performance below the level of learning.

5. Even after the effect of decremental factors has been discounted, the pursuit rotor shows better retention than does the nonsense syllable list. The superiority of the pursuit rotor may be attributed to its more unitary nature or to its freedom from the retroactive interfering effects of daily verbal behavior.

(Manuscript received April 18, 1944)

BIBLIOGRAPHY

1. BELL, H. M. Rest pauses in motor learning as related to Snoddy's hypothesis of mental growth. *Psychol. Monogr.*, 1942, **54**, No. 243.
2. DORÉ, L. R., & HILGARD, E. R. Spaced practice as a test of Snoddy's two processes of mental growth. *J. exp. Psychol.*, 1938, **23**, 359–374.
3. FREEMAN, F. N., & ABERNETHY, E. M. Comparative retention of typewriting and of substitution with analogous material. *J. educ. Psychol.*, 1930, **21**, 639–649.
4. FREEMAN, F. N., & ABERNETHY, E. M. New evidence of the superior retention of typewriting to that of substitution. *J. educ. Psychol.*, 1932, **23**, 331–334.
5. HOVLAND, C. I. 'Inhibition of reinforcement' and phenomena of experimental extinction. *Proc. nat. Acad. Sci.*, 1936, **22**, 430–433.
6. HULL, C. L. The meaningfulness of 320 selected nonsense syllables. *Amer. J. Psychol.*, 1933, **45**, 730–734.
7. HUSBAND, R. W. Analysis of methods in human maze learning. *J. genet. Psychol.*, 1931, **39**, 258–278.
8. KOERTH, W. A pursuit apparatus: Eye-hand coordination. *Psychol. Monogr.*, 1922, **31**, No. 140.
9. McGEOCH, J. A. The comparative retention values of a maze habit, nonsense syllables, and rational learning. *J. exp. Psychol.*, 1932, **15**, 662–680.
10. McGEOCH, J. A. *The psychology of human learning, an introduction.* New York: Longmans Green, 1942, Pp. 633.
11. McGEOCH, J. A., & MELTON, A. W. The comparative retention values of maze habits, and of nonsense syllables. *J. exp. Psychol.*, 1929, **12**, 392–414.
12. RENSHAW, S., & POSTLE, D. K. Pursuit learning under three types of instruction. *J. gen. Psychol.*, 1928, **1**, 360–367.
13. RENSHAW, S., & SCHWARZBECK, W. C. The dependence of the form of the pursuitmeter learning function on the length of the interpractice tests: II. Theoretical. *J. gen. Psychol.*, 1938, **18**, 17–29.
14. SCHLOSBERG, H. An inexpensive memory drum. *J. exp. Psychol.*, 1941, **29**, 161–163.
15. SEASHORE, R. H. Stanford motor skills unit. *Psychol. Monogr.*, 1928, **39**, 51–66.
16. TRAVIS, R. C. Practice and rest periods in motor learning. *J. Psychol.*, 1936, **3**, 183–187.
17. TRAVIS, R. C. The effect of length of the rest period in motor learning. *J. Psychol.*, 1936, **3**, 189–194.
18. TSAI, C. A comparative study of retention curves for motor habits. *Comp. Psychol. Monogr.*, 1924, **2**, No. 11.
19. VAN TILBORG, P. W. The retention of mental and finger maze habits. *J. exp. Psychol.*, 1936, **19**, 334–341.
20. WATERS, R. H., & POOLE, G. B. The relative retention values of stylus and mental maze habits. *J. exp. Psychol.*, 1933, **16**, 429–434.
21. WEBB, W. W. Massed versus distributed practice in pursuitmeter learning. *J. gen. Psychol.*, 1933, **8**, 272–278.

A NEW STABILOMETER FOR MEASURING DYNAMIC EQUILIBRIUM IN THE STANDING POSITION

BY ROLAND C. TRAVIS

Stanford University

Recognizing the need for a standardized technique for measuring a person's ability to maintain steady balance while standing on an unstable platform, the author designed an instrument keeping in mind three important requirements. First, to present a real challenge to the individual in his attempts voluntarily to control his basic posturing mechanisms mediated through a number of important sense fields. Secondly, to employ apparatus and procedure duplicable in other laboratories. Thirdly, to give an objective score easily read from an electric counter indicating the adequacy of postural balance.

The essentials of the present model of this new stabilometer (Fig. 1) consist of: (1) a platform mounted on a universal joint with an extension spring fastened between each corner of the platform and the base which supports the housing of the universal joint; (2) a hinged stylus which moves over and makes contact with a small target as the platform moves; (3) an electric interval timer or interrupter (sold by the Arthur H. Thomas Co., Philadelphia) set at intervals of $\frac{1}{5}$ sec.; and (4) an electric counter (either Stoelting counter or the Gorrell Hi-Speed counter) which is actuated five times per sec. through the interval timer when the individual's balance is sufficiently accurate to keep the stylus on the target.

The platform (sturdy pine board 4 cm. by 27 cm. by 36 cm.) on which the individual stands is mounted on a universal joint (from a used motor car) and is 32 cm. above the floor level. The lower housing of the universal joint is mounted firmly in the baseboard, which is slightly larger than the platform to give stability to the setup as a whole. The upper end of the universal joint is bolted firmly to the platform at a point equidistant from the two ends and the two sides. The two axes of rotation of the universal joint are approximately eight cm. below the level of the top surface of the platform. The tension of the four springs is adjusted to keep the platform level and to keep the stylus on the center of the target when the apparatus is not in use. The springs are made of steel spring wire (0.11 in. in diameter); they are 13.5 cm. in length when in place on the platform and nine cm. when released. They are 19 mm. in diameter.

The hinged stylus (made of brass rod $\frac{1}{8}$ in. in diameter, 17.5 cm. long) is mounted in cone bearings to an offset which extends 21 cm. above the top surface of the platform and six cm. in front of the leading edge. This arrangement prevents any force greater than the weight of the stylus from being brought to bear on the target. The target (one cm. in diameter) is the flattened head of a brass bolt sunk flush with the surface of a small bakelite platform (10 cm. square) which is mounted to an offset from the base of the main platform. The brass target and the bakelite platform are polished to present a smooth surface to the stylus. The total distance from the center of rotation of the main platform to the target is 51 cm.

The wide range of the tilting-movement of the platform permitted by the universal joint made restrictions of platform movement necessary. This was done by extending a wooden support from the base to a point three cm. from the lower surface of the platform near each corner. This arrangement permits the stylus to remain on the target platform in spite of excessive imbalance on the part of the *S* and at the same time allows sufficient tilting of the main platform to present a real task to the balancing skill of the *S*.

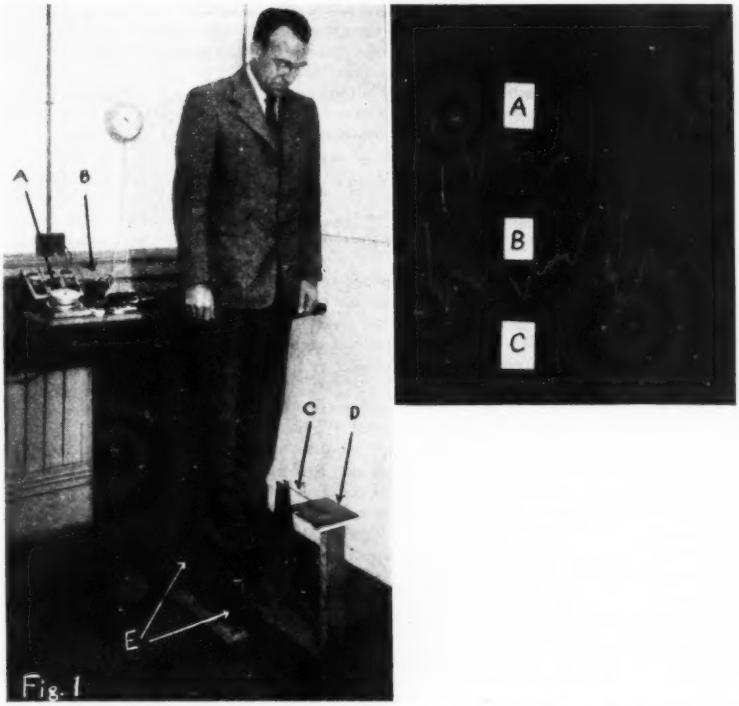

FIG. 1. The dynamic stabilometer. A—electric counter; B—interrupter (five times per sec.); C—hinged stylus mounted in cone bearings; D—target platform; E—tension springs.

FIG. 2. Sample record from the stabilometer. A—lateral component; B—antero-posterior component; C—interrupter score in fifths of a sec.

The size of the target, the distance of the target from the center of rotation of the platform, the tension of the four springs which control the ease with which the platform is tilted are factors which necessitated an empirical adjustment to secure an optimum difficulty of the balancing task. Many preliminary trials were necessary in varying systematically these three factors together with the consideration of individual differences before a practical setup was finally accomplished. The present particular combination of these factors in our setup restricts the tolerance of movement of the platform to *two degrees* if a continuous score is obtained. No one has yet attained a perfect score (300) and no one has scored below 30 (10 percent of perfect score) among the 321 college men and women so far tested.

The task of the individual being tested is to stand on the main platform, feet together, hands at the sides, eyes focused on the target, and to attempt to keep the stylus on the target continuously for one minute. The physical characteristics of the stabilometer present a decided instability whenever live weight is imposed upon it. The instability increases with increased weight, increased height, and increased fatigue. The continual slight shifts in body weight require the employment of fine neuro-muscular co-ordinations to a ballistic bodily function. A preliminary short trial was given each *S* to adjust his feet to a position on the platform which he considered most favorable with the restriction that his toes and heels be kept together.

Fig. 2 shows a smoked drum record of the lateral and antero-posterior movements of the stabilometer at a point equal in distance from the center of rotation to the end of the hinged stylus.

Record A shows the lateral component; record B the antero-posterior component; and C the interrupter score in fifths of a sec. The *S* for this record was a woman weighing 101 pounds, and her balance score for the duration of this particular record (about 14 seconds) was 81% of a perfect score, which is about average for her weight.

Records A and B indicate the slight shifts in the body weight of the *S* and her fine voluntary corrective movements not only in maintaining balance but also in attempting to keep the stylus on the target. When the latter was accomplished the marker produced a continuous series of vertical marks in intervals of one-fifth of a sec. shown at C.

To decrease the psychological hazard and to prevent the *S* from accidentally falling off, a protective railing about waist high was placed on the left and in front of the platform in easy reach of the *S*. A high table which supported the interval timer, the counter and dry cells was placed just back of the platform and served as a seat for the *S* between trials, his feet remaining on the platform.

The cues contributing to the successful performance of this task are sensory data from visual, auditory, kinesthetic, vestibular, and cutaneous excitation, and perhaps also from organic excitation. Visual cues (aligning the stylus on the target) make possible fine co-ordinated neuromuscular adjustments. The relative effectiveness of visual cues in this performance is evident in the fact that the score with visual cues on the average is more than three times as great as the score without visual cues.

Auditory cues are brought into play in the operation of the electric counter which clicks five times per sec. when the stylus is on the target. When visual cues are excluded, the distinct audible clicking of the counter when the stylus is on the target and the absence of the clicking when the stylus is off the target are the obvious cues to the *S* of the effectiveness of his performance. Other less obvious cues in terms of the combined sensory data (kinesthetic, cutaneous, vestibular, organic) aside from the auditory cues in the situation without vision give the *S* information as to the general level of the unstable platform, a rather gross approximation to say the least. In other words, without visual and auditory cues the *S* must more or less grope his way around in a mixture of reflex and voluntary adjustments of his body weight with his ankles as the main pivot.

For some *S*s the task is extremely difficult without visual cues, making frequent touching of the rail necessary. Two college men found the task impossible without visual cues. One of these men reported having had an attack of infantile paralysis when a child, although aside from a slight awkwardness his general appearance and bodily movements seemingly were quite normal. The other man reported nothing unusual.

Experimental Results

Table I gives the weight and height groupings, the number of cases (N), the mean performance scores (M), and the variability (S.D.) for each weight group and each height group for the 164 college men and 157 college women. Figs. 3 and 4 show graphically the data given in Table I. Fig. 3 shows the relationship between weight groups and the balancing score (percentage of a perfect score) for the men (solid line) and the women (broken line). The mean scores (small crosses) and standard deviations (horizontal bars) indicate some variability from weight group to weight group and also disclose a rather high negative correlation, − .70 (P.E. = .027) for the men and − .82 (P.E. = .018) for the women between balancing score and weight. Fig. 4 shows the relationship between balancing score and the height groups for the men and the women. The negative correlation coefficient between balancing score and height for the men was − .44 (P.E. = .043) and for the women − .63 (P.E. = .035).

TABLE I

THE NUMBER OF CASES, THE MEANS AND THE STANDARD DEVIATIONS FOR THE DIFFERENT WEIGHT AND HEIGHT GROUPS FOR 164 COLLEGE MEN AND 157 COLLEGE WOMEN (POSTURAL BALANCE)

Weight pounds	Men			Women			Height inches	Men			Women		
	N	M	S.D.	N	M	S.D.		N	M	S.D.	N	M	S.D.
200	2	14	—				76	3	13	2			
195	2	32	2				75	3	38	15			
190	6	27	14				74	9	30	13			
185	10	32	11				73	12	43	7			
180	10	38	11				72	25	43	9			
175	12	40	10	1	42	—	71	31	45	15	3	50	6
170	8	39	12	1	30	—	70	22	48	15	6	51	10
165	21	41	13	4	46	9	69	17	54	10	7	63	12
160	22	48	7	3	50	3	68	22	52	7	14	63	11
155	17	50	12	7	53	11	67	12	53	11	25	64	10
150	20	53	10	7	52	11	66	4	53	19	31	63	10
145	14	54	5	12	59	10	65	4	46	16	20	69	14
140	8	54	10	16	60	9	64				20	76	9
135	4	71	6	19	64	6	63				10	74	10
130	5	61	11	18	68	7	62				11	79	8
125	3	65	8	13	70	10	61				7	81	5
120				12	77	5	60				3	86	3
115				15	77	4							
110				13	82	6							
105				12	83	4							
100				4	89	4							

The mean score for each weight group and each height group represents the average of the scores for the first three trials. The trials were one min. in length with one-min. rest periods between trials.

The correlation between weight and height for the 321 college men and women combined was .67 (P.E. = .021).

It is evident from the graphs, from the relatively high negative correlations between balancing scores and weight and between balancing scores and height, and from the relatively high correlation between weight and height, that the heavy-weight or tall person has greater difficulty in controlling his postural balance than a light-weight or short person. Preliminary attempts to control technically through the apparatus the factors of weight and height in this study were only partially successful and thus were abandoned in favor of the present statistical division of the performance scores into weight and height groupings.

Five factors (aside from the individual's skill in maintaining balance) are important in keeping the stylus on the target, namely, (1) the size of the target, (2) the distance of the target from the center of the platform, (3) the tension of the springs, (4) the increased instability of the platform with increased weight at any given height,

and (5) the increased instability of the platform with a given weight imposed at increasing height. Let us discuss these factors in turn. In the case of factor (1), to change the size of the target in accordance with weight and height, that is, to have a series of different targets

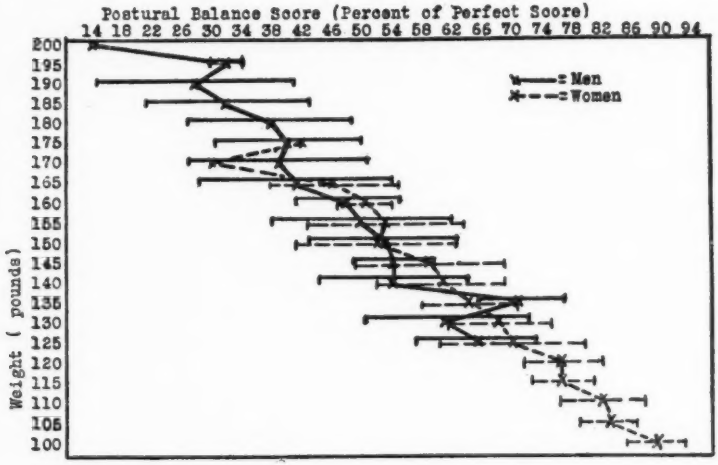

FIG. 3. Weight and balancing score for 164 men and 157 women.

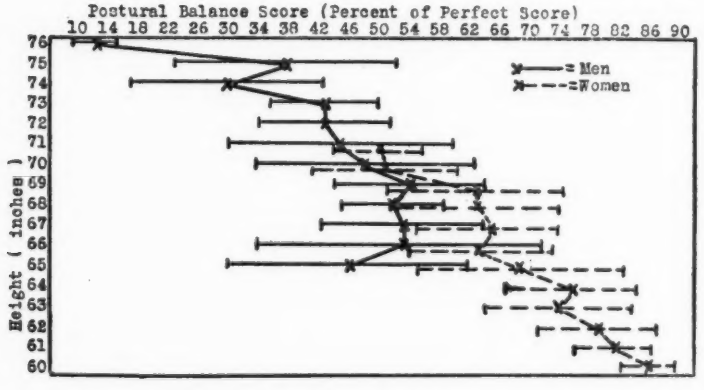

FIG. 4. Height and balancing score for 164 men and 157 women.

varying in size to correspond to different weight values and height values proved to be a technical hazard which would make validation an extremely laborious process. Factors (2) and (3) come under the same category as factor (1). In one attempt, factor (3) was partially

controlled by using compression springs and permitting the universal-joint housing to move up and down within a smooth bearing, thus changing the tension of the springs according to the weight imposed upon the platform. This arrangement, however, failed to control the height factor. Factors (4) and (5) have to do with absolute weight and absolute height and the distribution of weight throughout the body axis. An adequate consideration of factors (4) and (5) would involve a systematic exploration of the center of gravity of the body in relation to postural balance.

A small sex difference was obtained in the balancing score in comparable weight groups and height groups in favor of the women. This difference for the height groups (9 percent) approaches statistical significance with a critical ratio of three. When the average weights for the men and the women in comparable height groups were calculated and compared, the total average difference was 13 pounds in favor of the men. This difference in weight undoubtedly accounts for at least part of the difference in balancing scores for the men and women. The overlapping in weight groups for the two sexes occurred between weights of 120 pounds and 175 pounds. The cases above 175 pounds were all men and those below 125 pounds were all women. The overlapping in the height groups occurred between 65 inches and 71 inches. All cases 72 inches and above were men and all cases below 65 inches were women.

The reliability of the stabilometer was ascertained by correlating the first trial with the second trial, the second trial with the third trial, and the first trial with the third trial for the entire group of 321 college men and women. These correlations in the situation with visual cues were as follows: trial one with trial two .86 $\pm$ .01, trial two with trial three .85 $\pm$ .011, and trial one with trial three .80 $\pm$ .014. These correlations represent a fairly high degree of consistency.

On the average a small amount of learning is exhibited during an extended series of trials. In a study of 22 college men and 22 college women using eight one-min. trials with one-min. rest periods between trials a slight average gain for both groups of seven percent was found between the average of the first two trials and the average of the last two trials. A few *Ss* may almost double their scores, a few show a decrease in score as trials continue, but most *Ss* exhibit a small gain. This small gain for most *Ss* was obtained in the two situations, with and without visual cues.

In the situation with visual cues excluded for 22 men and 22 women the performance scores on the average were about one-third as high as those with visual cues present. Here again the same relationships between scores and weight and height were obtained.

The *r*'s between trial one and trial two, between trial two and trial three, and between trial one and trial three were .80 or above.

Preliminary studies have shown that individuals reporting fatigue, recent imbibing of alcohol, loss of sleep, or recent violent exercise tend markedly towards inadequacy in performance of this type, whereas those reporting previous training in dancing, skiing, gymnastics and skating tend towards a performance far above normal.

(Manuscript received April 24, 1944)